NASA TECHNICAL
MEMORANDUM

NASA TM X-53720

April 3, 1968

NASA TM X-53720

DESIGN AND DEVELOPMENT OF THE HAZARDOUS GAS DETECTION SYSTEM FOR LAUNCH VEHICLE PROPELLANT LOADING AND CHECKOUT

By C. L. Perry, A. C. Krupnick, and R. J. Harwell
Propulsion and Vehicle Engineering Laboratory

NASA

George C. Marshall
Space Flight Center
Huntsville, Alabama

TECHNICAL MEMORANDUM X-53720

DESIGN AND DEVELOPMENT OF THE HAZARDOUS GAS DETECTION SYSTEM FOR LAUNCH VEHICLE PROPELLANT LOADING AND CHECKOUT

By C. L. Perry, A. C. Krupnick, and R. J. Harwell

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

ABSTRACT

This report describes the development of an apparatus for remotely monitoring the gas purge environments of the Saturn launch vehicle systems during the prelaunch and checkout period. The apparatus was designed around a remotely controlled mass spectrometer with solenoid-operated sampling valves which allow surveillance of selected areas within the vehicle. The system consists of slightly modified commercial components. The modifications do not destroy normal manual operation capabilities of the equipment. All the versatility of the mass spectrometer is retained for possible use as an analytical mass spectrometer when the system is not being used to support a launch vehicle test.

The combination of remote control, long distance operation, and multiple sampling over long distances is a unique application of the mass spectrometer technique of analysis.

With this system considerable time, money, and manpower can be conserved. Direct analytical assay also eliminates, to a large extent, the long time requirements of laboratory analysis.

The Appendix presents the historical sequence in the development of the Hazardous Gas Detection System (HGDS) to show the problems that had to be solved and the various improvements made between the various Saturn I launches to support additional analytical requirements established by Kennedy Space Center (KSC).

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER

TECHNICAL MEMORANDUM X-53720

DESIGN AND DEVELOPMENT OF THE HAZARDOUS GAS DETECTION SYSTEM FOR LAUNCH VEHICLE PROPELLANT LOADING AND CHECKOUT

By C. L. Perry, A. C. Krupnick,
and R. J. Harwell

PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Concluded)

TECHNICAL MEMORANDUM X-53720

DESIGN AND DEVELOPMENT OF THE HAZARDOUS GAS DETECTION SYSTEM FOR LAUNCH VEHICLE PROPELLANT LOADING AND CHECKOUT

SUMMARY

An apparatus for remotely monitoring hazardous gases in the purged areas of a Saturn launch vehicle system has been developed. The apparatus was designed around a remotely controlled mass spectrometer with solenoid operated sampling valves which allow surveillance of selected areas within the vehicle during prelaunch propellant loading operations. The system consists of slightly modified commercial "off-the-shelf" components. The modifications do not destroy normal manual operation capabilities of the equipment. All the versatility of the mass spectrometer is retained for possible use as an analytical mass spectrometer when the system is not being used to support a launch vehicle test.

The combination of remote control, long distance operation, and multiple sampling over long distances is a unique application of the mass spectrometer technique of analysis. The system is capable of direct or computerized remote operation.

In addition to this technical presentation of the Hazardous Gas Detection System (HGDS), the historical developments are considered to be of sufficient merit to record as an Appendix to show the problems to be solved and the progress of the HGDS development and the improvements made between various Saturn launches.

INTRODUCTION

This report presents the technical development of the mass spectrometer HGDS used at Kennedy Space Center (KSC) for launch vehicle propellant and oxidizer loading operations. The HGDS is designed around commercially available laboratory equipment which has been modified to be operated remotely without destroying the versatility of the mass spectrometer equipment. The HGDS is designed to manually sweep-scan from atomic mass 1 through 150 or to preselect up to six different gases in a mixture. Under the present requirement, the HGDS is set up to detect and quantitatively analyze for hydrogen, oxygen, helium, and nitrogen, and to detect nitrogen tetroxide and the hydrazine derivatives.

The initial design concept for the HGDS was developed during the first part of 1964 as a leak checking device for the interstage compartments of the Saturn IB and Saturn V systems. It was decided later to develop an automatically operated mass spectrometer system that could sample various areas within the interstage compartments for hydrogen gas by means of a scanner-valve manifold system. The scanner-valve concept was eventually eliminated because of cost and qualification time.

HAZARDOUS GAS DETECTION SYSTEM DEVELOPMENT

Since catalytic decomposition devices require a small amount of oxygen to function properly they cannot accurately monitor for hydrogen in areas which contain high concentrations of inert gases. Therefore, it was necessary to develop an analytical system that would circumvent this problem. It was believed that such a detection system could be developed around mass spectrometer techniques from existing laboratory equipment. In addition to the assay of hydrogen, the analytical instrumentation was to be capable of monitoring for oxygen and possible hypergols such as N_2O_4 and the hydrazine derivatives.

The task was to assemble a system that would be capable of: (1) remote electrical operation over 1700 feet of hard wire, (2) obtaining a representative sample from the vehicle, (3) pumping the sample approximately 175 feet through pneumatic lines to an analyzing device within a minimum amount of time, and (4) operating for at least 24 hours without access for maintenance or adjustment.

During the Saturn launch program, beginning with SA-7 and continuing through AS-201, the HGDS was developed into its final form as shown in Figure 1. The actual hardware shown here is in use on the Saturn IB launch pads. The Unit is controlled and read out remotely by hard wire connections, and is isolated from all other systems; i.e., no data links are used. On Saturn V the system is remotely controlled through the RCA computer, and data are transmitted via the Digital Data Acquisition System (DDAS). These differences in control and readout require slightly different control panels and one minor electronic change to the vacuum gauge; otherwise, the units are nearly identical in mechanical and electrical configuration. Basically, the system is a mass spectrometer with a continuous inlet system. The instrument system was developed during the Saturn I program with system changes being made between launches to improve performance. The mass spectrometer and vacuum system are in the left cabinet (Fig. 1) and calibration gas is in a bottle in the adjacent cabinet. Local control panels are in an adjacent rack (not shown) and remote control panels are located in the blockhouse or launch control center. One-fourth inch stainless steel sample lines are brought into the top of the rack, and the areas to be selected for monitoring are controlled by remotely operated self-manifolding solenoid valves.

Panel A in the rack is a Granville-Phillips automatic pressure controller which provides constant sample pressure for the mass spectrometer. Panel B contains a Cryogenics, Inc., liquid nitrogen (LN_2) level controller which automatically maintains LN_2 for the vacuum system and also a Consolidated Vacuum Corporation thermocouple gauge controller which automatically operates the diffusion pump. Panels C, D, and E are the Consolidated Electrodynamics Corporation mass spectrometer panels. Panel F is a Granville-Phillips ionization vacuum gauge controller which provides a control signal to the automatic pressure controller and a readout signal for remote monitoring of the vacuum system. Panel G is an automatic peak selector for the mass spectrometer. This panel can be programmed and tuned to any mass number from 2 to 150, and allows monitoring of up to 6 individual mass numbers. The time cycle for this unit is 15 seconds for each mass number plus 15 seconds reset at the end of each cycle. Panel H houses the sample selection manifold which allows the selection of a vehicle compartment or a standard calibration gas. The hand valves on the front allow balancing of the pressure in the manifold for better sample control. The control panel can be designed to permit manual operation of this sampling manifold, automatic valve sequencing, or both. The vacuum system is in the bottom of the rack cabinet.

The vacuum system shown in Figure 2 consists of slightly modified off-the-shelf hardware which fits into the lower one-third of a standard 19-inch relay rack and requires ac power, water, and LN_2 for operation. Operation of the vacuum system is semi-automatic. The diffusion pump is operated by a thermocouple vacuum gauge which senses the foreline pressure. The diffusion pump is further protected by a thermostat, a water pressure switch, and a quick-cool solenoid valve. A water cooled chevron baffle isolates the diffusion pump from the liquid nitrogen cold trap thus preventing back-streaming of oil into the main vacuum chamber. A permanent magnet provides the field for the cycloidal focussed mass spectrometer.

The sampling system is a double by-pass system which gives fast response over long sampling distances. A high velocity of gas flow (25 feet per second) is brought from the vehicle location being sampled, and the major portion of the gas is exhausted by the sample pump. However, part of this sample is taken out of the manifold and flows through the automatically controlled variable leak past a gold orifice which picks up a small portion of the gas flow for analysis by the mass spectrometer. The sampling system is shown schematically in the Appendix, Figure A-3. Response time from the valve manifold inlets for readout is practically instantaneous. The sample response time varies depending on the distance between the area being sampled and the HGDS. The greatest response time experienced in application of the HGDS was approximately 50 seconds where the area being sampled was several hundred feet from the HGDS.

The control panel for the Saturn IB units is shown in Figure 3. It consists of two rows of buttons which control a transistorized switching network. Recorders record the condition of the vacuum system and the mass spectrometer readout. Control from this panel is manual except that the peak selector can be set to analyze automatically up to six gases or to hold on any one of the six for continuous analysis of a single gas.

The control panel for the Saturn V unit is shown in Figure 4. Command of control functions is accomplished through the ground computer and all readout signals are transmitted by the DDAS. With this panel, the sample selection valves can be set to operate sequentially, thus giving fully automatic monitoring of the launch vehicle.

The HGDS, being a gas analyzer, can be used to monitor the environment of an interstage area. It can show the depletion of a gas species due to a change in the purge gas as well as the quality of the purge. Figure 5 shows the real time data observed with the HGDS on AS-201 Countdown Demonstration Tests (CDDT) during change-over of the Environmental Control System (ECS) purge from air to GN_2. The peak selector was stopped on the oxygen peak for continuous monitoring. The valve manifold was used to select the S-IVB (second stage) aft interstage compartment. As the GN_2 purge starts, the 21 percent O_2 concentration begins to deplete rapidly. The peak selector was returned to automatic operation to scan for background, N_2, H_2, He, and O_2. It was found that the O_2 concentration had dropped to 2.5 percent within three minutes. After one additional peak selector cycle, the O_2 concentration was down to 0.25 percent (Fig. 6). The ramp functions in Figures 5 and 6 identify the gas constituent being analyzed. The additional data shown in Figure 6 indicate the rapid reaction time of the HGDS and its sensitivity to changes within the interstage. It can be seen that the O_2 concentration began to rise suddenly, to 10 percent by volume, and then began decreasing. Communication with the test conductor verified a short loss of GN_2 purge due to an error in following the procedures used in converting the purge from air to GN_2. This error allowed a "slug" of air to be forced into the S-IVB aft interstage compartment.

It was suggested that the HGDS be used to detect the 14 pound-per-minute engine chilldown purge of the S-IVB engine. This chilldown was to take place at T-2:14 in the CDDT. During a hold at T-3:20, the data shown in Figure 7 were observed while surveying the vehicle. It can be seen that about one percent helium is present in the S-IVB and none is present in the IU. The O_2 content in both areas is below 0.25 percent. The one percent volume of helium shown here back-calculates to 1/4-pound per minute helium purge based on a 160 pound-per-minute GN_2 purge. This small amount seen here was not the chilldown helium purge, but, according to KSC personnel in the blockhouse, was a small trickle purge preliminary to the chilldown. The test was terminated during the hold at T-3:20, so the actual 14 pounds per minute was never used.

CONCLUSIONS

Based on the data obtained in this development program, the HGDS will provide continuous, accurate, and sensitive surveillance of interstage environment of both the Saturn IB and the Saturn V launch vehicles during propellant and oxidizer loading until launch takes place. Due to the flexibility of the HGDS and its ability to provide laboratory analytical type data, the utilization of this equipment not only provides monitoring assay of the hazardous gases such as hydrogen, oxygen, and hypergol vapors, but may also be used for checking the inerting conditions within the launch vehicle tanks, transfer lines, and ground support equipment if desired. Implementation of the HGDS's present degree of versatility could be afforded by simply connecting the HGDS via bypass sampling lines to the gas system requiring surveillance since the system retains the flexibility of standard laboratory equipment. The system may be used to monitor any gas mixtures and quantitatively analyze for any constituent from mass 2 to 150. Some difficulty may occur in the analysis of a continuing hypergol-fuel leak since the sampling system has a long memory for these compounds and will not pump clean. Also, some problems may arise in selecting calibration gases for hydrazine derivatives since they are normally liquid with low vapor pressures. However, it is expected that if this system is used to its fullest capability, considerable money, time, and manpower could be conserved with the ability, as afforded by the HGDS, to assay at will pressurizing gases utilized on the launch complexes prior to and during launch. Direct analytical assay could eliminate to a large extent the long time requirement of laboratory analysis as practiced at this time.

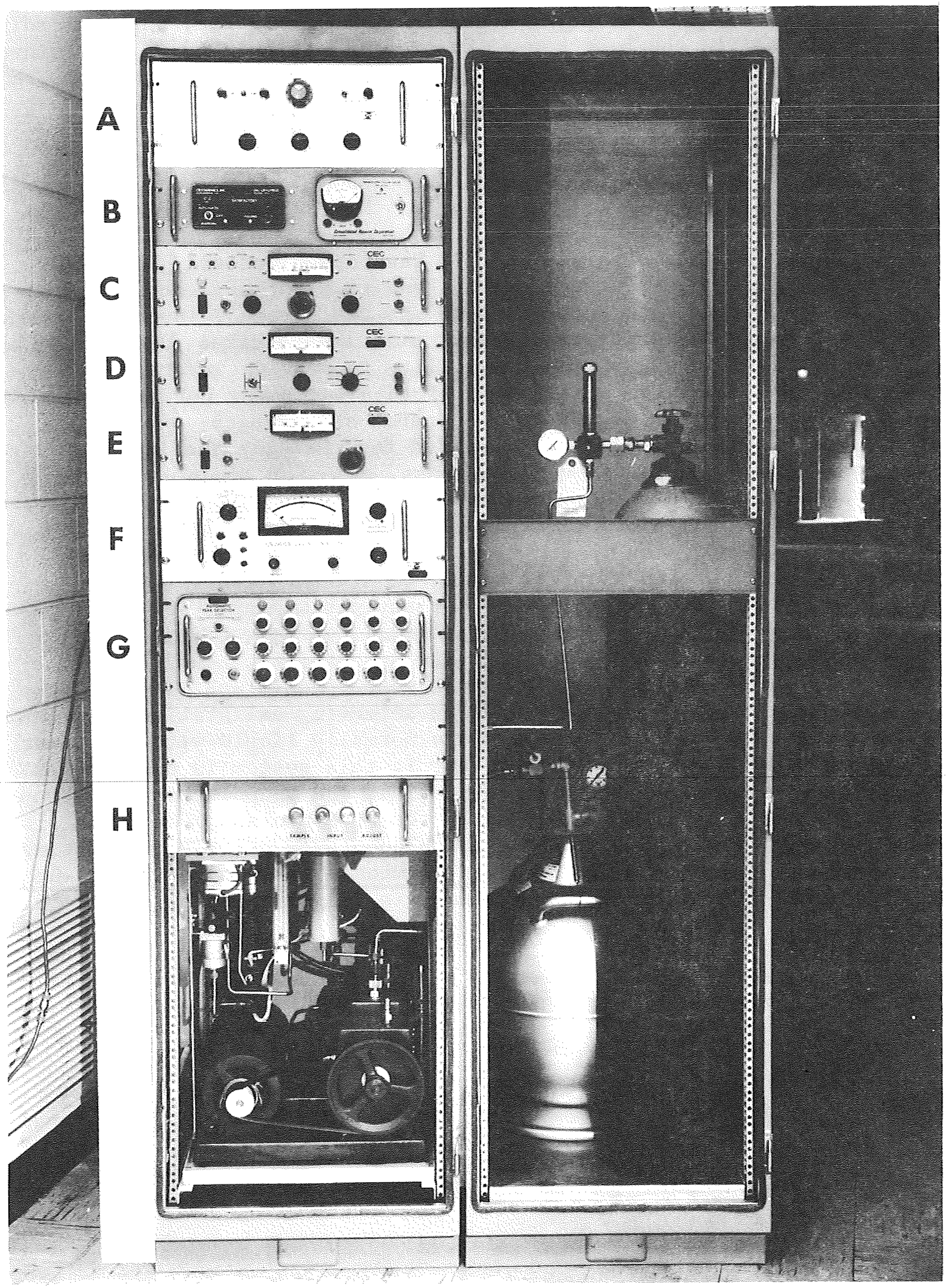

FIGURE 1. - HAZARDOUS GAS ANALYZER

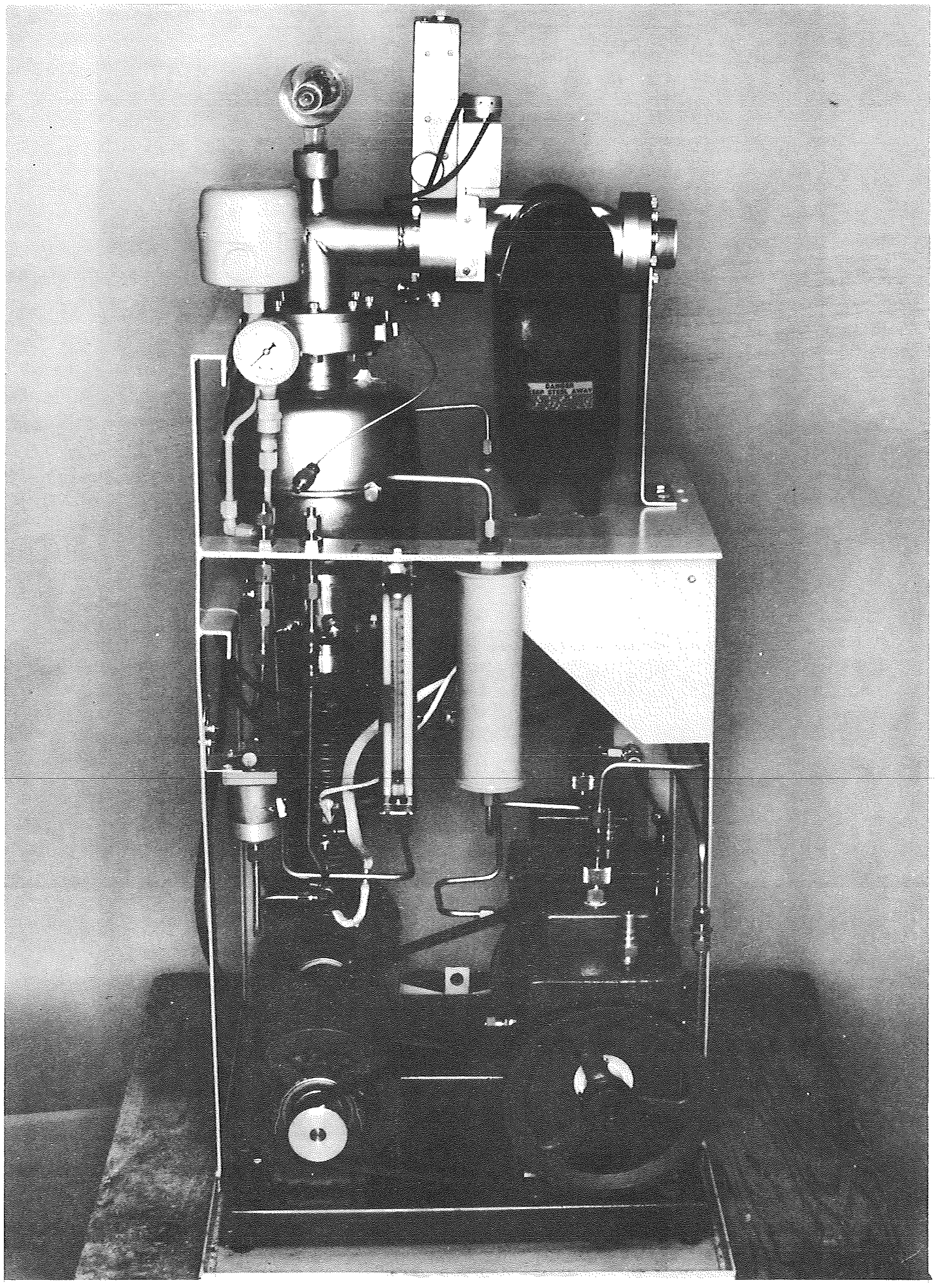

FIGURE 2. - HAZARDOUS GAS ANALYZER VACUUM SYSTEM, FRONT VIEW

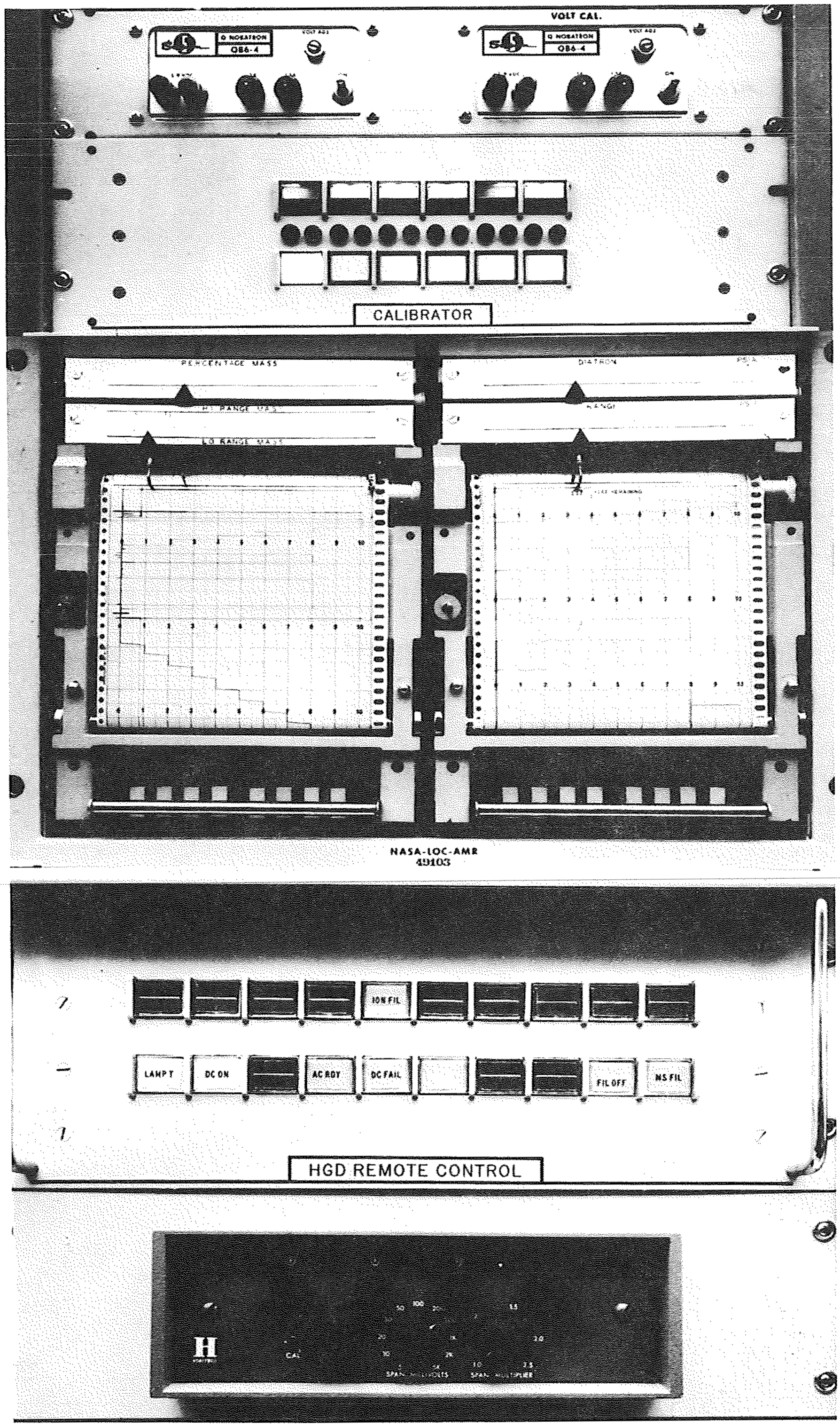

FIGURE 3. - BLOCKHOUSE REMOTE CONTROL PANELS, SATURN IB

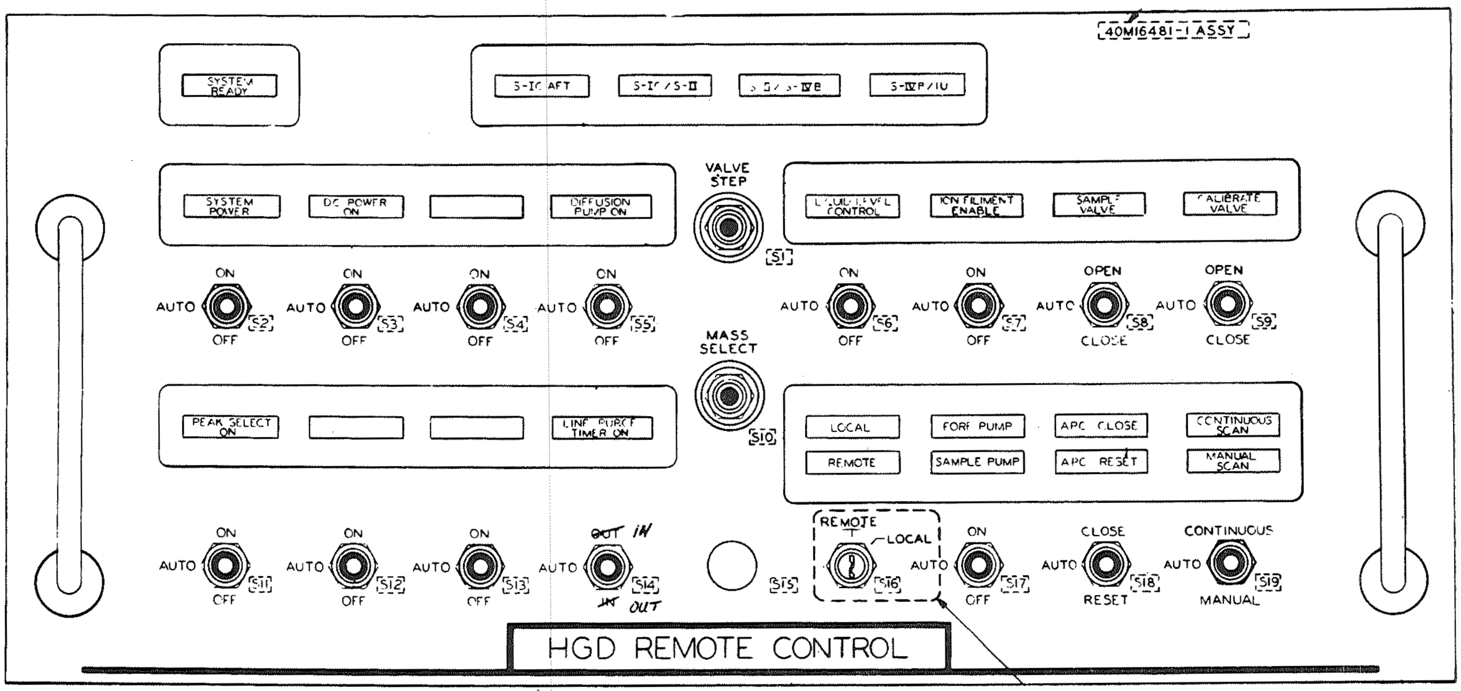

FIGURE 4. - FIRING ROOM CONTROL PANEL, SATURN V

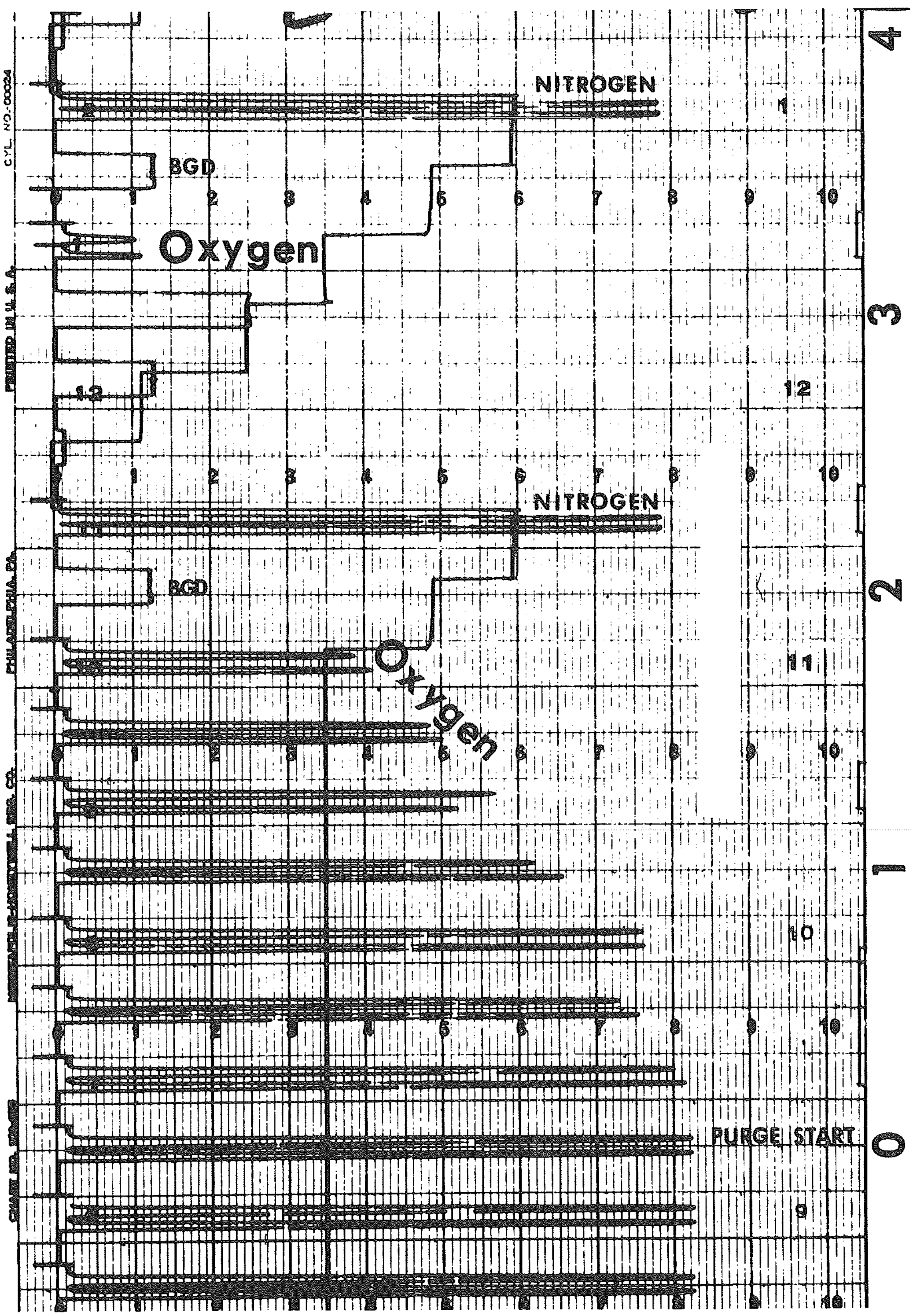

FIGURE 5. - S-IVB ENVIRONMENT CONTROL SYSTEM SHIFT TO GASEOUS NITROGEN, AS-201

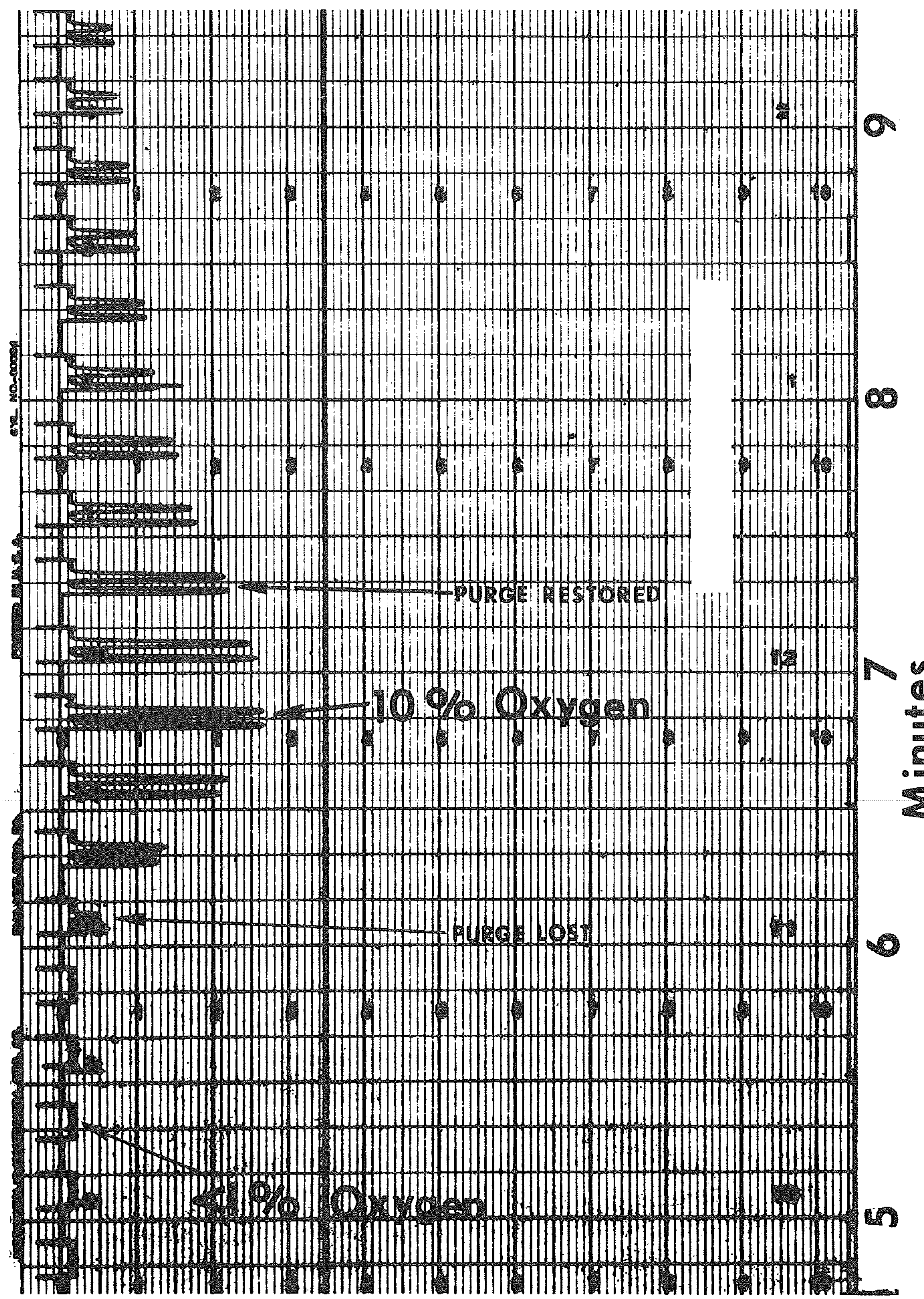

FIGURE 6. - LOSS OF GASEOUS NITROGEN PURGE, S-IVB, AS-201 CDDT

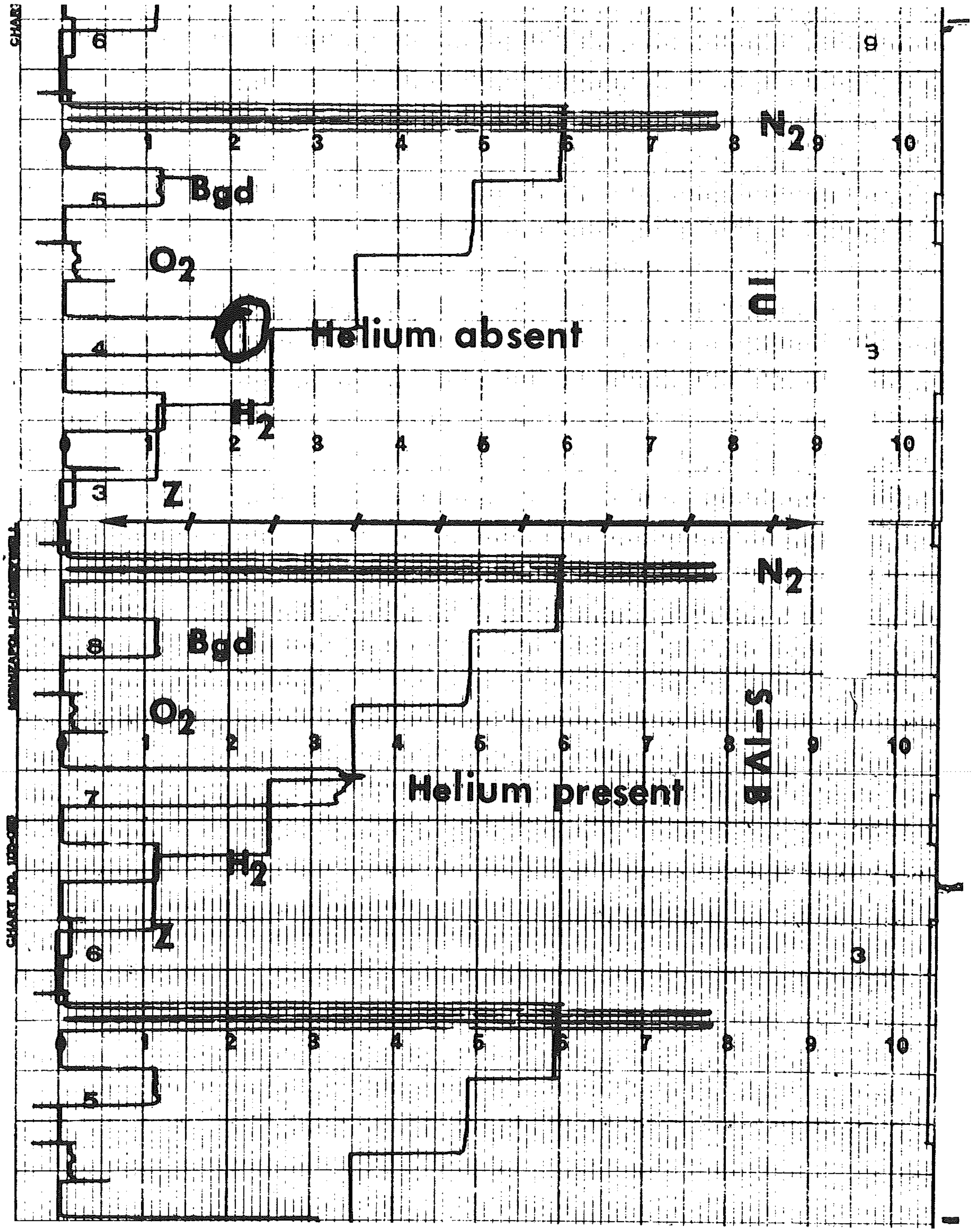

FIGURE 7. - APPEARANCE OF HELIUM IN S-IVB,
AS-201 COUNTDOWN DEMONSTRATION TEST

APPENDIX

HISTORICAL SEQUENCE OF DEVELOPMENT

Saturn I, SA-7

Only three weeks were available to arrive at a workable analytical system prior to the launch of SA-7. All items for the unit had to be assembled from modified equipment available in the laboratory. A Consolidated Electrodynamics Corporation (CEC) Diatron Model 21-611 type residual gas analyzer was available for use; however, it had to be modified to sample gases at atmospheric pressure. Therefore, the envelope of the "Diatron" was bored and flanged to accept a gold-leak orifice (molecular leak), capillary tube, and bypass flange normally used as a continuous inlet system on a CEC Model 21-620 mass spectrometer.

The vacuum system shown in Figure A-1 was assembled using a Welch Duo-Seal Model 1400B forepump and an air cooled diffusion pump. A liquid nitrogen cold trap approximately 5-inches O.D. by 3-inches I.D. by 4-feet long was fabricated in-house to allow operation in the 10^{-6} torr pressure range for approximately 24 hours. A second vacuum pump was used to draw gas from the area to be sampled. In addition, the second stage of the mass spectrometer vacuum forepump was fitted with a line to provide sample gas flow past the gold leak. Figure A-2 shows the vacuum gauge controller and analyzer power unit. A pictorial diagram of the system is shown in Figure A-3.

During the initial checkout it was determined that the instrument was extremely slow to respond. The cause was established as the standard capillary tube supplied with the Model 21-620 mass spectrometer which would not permit enough gas flow into the "Diatron" tube. A replacement capillary was fabricated from a 12-inch length of 1/16-inch O.D. thin wall stainless steel tubing. In order to provide the correct gas flow without overloading the mass spectrometer with sample and destroying pressure control of the vacuum, the tubing was crushed carefully along its length until the correct system response was acquired.

Upon verification that the modification was satisfactory, a 175-foot length of 1/4-inch O.D. tubing was connected to the gas inlet to simulate sampling conditions on the launch pad. It was found that the system could detect a change in gas composition within 7 to 8 seconds. The flow rate through 1/4-inch tubing using a one cubic foot per minute pump capacity was calculated to be about 70 feet per second assuming complete viscous flow conditions.

When the mass spectrometer was calibrated with 2.5 percent and 1.15 percent hydrogen in air, the data indicated a linear concentration response function as anticipated. The sensitivity of the mass spectrometer to this calibrating gas was 16 chart divisions for each percent of hydrogen. The estimated accuracy of the system was about ±10 percent of the levels observed. This estimate is based on the variation of output observed with an applied ±10 percent variation of the "Diatron" pressure from its preset level.

The mass spectrometer, with its vacuum pumps and pressure gauge, was installed in the Manometer Room of the Ground Support Equipment building on the launch pad. Temporary flexible metal hoses were used to cross the umbilical arms at the interstage areas. The output signals of the mass spectrometer and the pressure gauge were recorded in the blockhouse approximately 1700 feet distance. Output noise levels observed were generally slight and insignificant. Recorders that were located in the blockhouse recorded only the vacuum and the analyzer outputs. No control functions were provided at the recorders.

When the equipment was installed on the launch pad, 3/8-inch O.D. tubing was used instead of 1/4-inch tubing to connect the S-IVB interstage area to the instrument. The approximate distance from the interstage to the mass spectrometer was 175 feet. In a test using gaseous helium as a test gas, the response time of the sampling system was 1.5 to 2.0 minutes. At this time, optimum sampling conditions were not completely understood, leading to this error in sample tubing selection. Later, tests at MSFC with 3/8-inch, 1/4-inch, and 3/16-inch O.D. tubing indicated that 3/16-inch tubing gave a response time only slightly better than 1/4-inch tubing; however, since 3/16-inch tubing was not readily available at the launch complexes, 1/4-inch tubing was selected for future use.

During the Countdown Demonstration Test (CDDT), the monitor was calibrated and adjusted at 2 a.m. and left unattended during the test. No hydrogen leaks were indicated by the monitor during the test. After 18 hours, the launch pad was opened to personnel. Without making any instrument adjustments, the mass spectrometer was checked with hydrogen gas and was found to have functioned properly and reliably. Thus, it was determined that a system designed around the mass spectrometer principle was feasible to develop into a hydrogen gas monitoring system under the previously mentioned ground rules.

During the post-CDDT evaluation, it was requested that the Materials Division continue to provide improved hazardous gas monitoring surveillance during future propellant and oxidizer loading operations of the Saturn I launch vehicles.

Remote control panels were designed and fabricated to provide remote control of the "Diatron." The vacuum system and analyzer retained the appearance shown in Figure A-1. However, a solenoid valve allowed isolation of the vacuum pumps from the cold trap in case of power failure. A manifold was fabricated using 1/4-inch tube "T" fittings and 115 Vac solenoid valves to allow selection of either a calibrating gas or the interstage area for analysis by the instrument.

A front view of the new ac Power Control panel, the "Diatron" Control panel, and the Vacuum Gauge panel is shown in Figure A-4. Figure A-5 is a rear view of the same panels showing components and connections.

Electrical schematics of the local ac Power Control are shown in Figures A-6 and A-7. A rotary stepping switch allowed selection of the circuit to be energized or de-energized, and relays in each circuit held the power on until de-energized or a power failure occurred. A pilot light verified the power condition of each circuit selected and power inputs were cascaded to allow a fixed sequence of startup.

Figure A-8 shows an electrical diagram of five miniature relays installed in the vacuum gauge controller. These relays allow energizing the ion gauge tube and switching the readout range for more precise readout of the pressure.

The "Diatron" control was modified as shown in the diagram (Fig. A-9). A dc motor mounted on the zero control allowed the instrument gain to be adjusted. Miniature relays allowed switching of the mass range of operation, continuous scanning of all masses, control of the ionization filament, and attenuation of the output signal.

A remote control panel was designed and fabricated for use in the blockhouse. This panel is shown in Figure A-10. An electrical diagram of the mass spectrometer control section of this panel is shown in Figure A-11. The vacuum gauge section is shown electrically in Figure A-12, and the ac power control section is shown in Figure A-13.

The remote controls built for the instrument system allowed complete restart, calibration, and operation to monitor the total gas environment of the interstage. The remote control was located in the blockhouse of Launch Complex 37 and the mass spectrometer was again installed in the Manometer Room on the launch pad.

The sampling tubing system was changed to 1/4-inch O.D. tubing from the interstage to the mass spectrometer, replacing the 3/8-inch O.D. sample system used on SA-7. The response time was about 10 to 15 seconds with the 1/4-inch O.D. tubing, an improvement over the 1.5- to 2.0-minute response with the 3/8-inch O.D. tubing.

During a tanking test of SA-9, an accidental power failure caused the monitoring system to shut down after the launch pad area was cleared of personnel. The remote controls enabled the system to be successfully restarted from the blockhouse without returning to the launch pad.

During the tanking test, the monitor was used to observe the concentration of various gases within the S-I/S-IV interstage area through the use of the remote scanning controls. The instrument also was calibrated at frequent intervals with hydrogen, nitrogen, oxygen, helium, carbon dioxide, and argon using a pre-analyzed standard gas mixture to assure that the instrument could monitor for the above gases, both qualitatively and quantitatively, in the interstage areas. No leaks were observed while tanking and detanking of LH_2 or LOX during the loading test of SA-9.

The Environmental Control System (ECS) utilizes an air purge prior to inerting the interstage compartment with gaseous nitrogen (GN_2) before the liquid hydrogen (LH_2) tanking sequence. While monitoring the interstage oxygen depletion during the pre-purge and inerting sequence, it was found that the interstage compartment could be purged to less than one percent oxygen in approximately five minutes after GN_2 flush start-up (see Fig. A-14). The countdown procedure required a GN_2 purge time of 15 minutes prior to tanking LH_2. Figure A-15 shows a verification analysis that less than one percent of oxygen was in the interstage compartment during the GN_2 purge.

Because future tests would require the HGDS to function under launch conditions, it was decided to check the equipment under launch conditions. However, at the time of launch of SA-9, no umbilical sampling connections were available to the S-IV interstage compartment; therefore, a sampling line was run to the open air near the LH_2 "skid" (LH_2 complex-vehicle loading valve).

During the countdown and until T+2 minutes the system functioned as well as during the prelaunch operations. However, from T+2 to T+17 minutes, the recorders indicated erratic operation, and remote operational control was unsuccessful. At T+17, the system returned to normal operational capability. When the pad was cleared to permit access to personnel, it was learned that the Automatic Ground Control System Room housing the equipment had flooded with water from a line that had ruptured at lift-off. Approximately four inches of water stood around the equipment, and the spray appeared to have contacted the equipment.

Between the launch of SA-7 and SA-8, several different types of mass spectrometers were evaluated to determine what instrument was best suited for the HGDS. It was determined that the "cycloidal" type mass spectrometer was the most practical instrument for conditions that had to be met both in operation and overall performance. Due to the evaluation of the instrument system after the SA-9 launch and because of future requirements, it was determined that improvements of the existing equipment were required in order to obtain greater instrument sensitivity, resolution, accuracy, and reliability.

The "Diatron" mass spectrometer used so far, in addition to being a 12-year old instrument, began showing signs of wear due to repeated assembly, disassembly, and transportation of the system between Huntsville and Cape Kennedy. Another mass spectrometer (Consolidated Electrodynamics Corporation Model 21-614) with a continuous inlet system and a high speed peak selector was selected for a new system because it filled the requirements of the program and the requirements of the instrument operation evaluation.

Saturn I, SA-8

The entire system was redesigned as follows: The vacuum system was changed by replacing the air cooled diffusion pump with a Consolidated Vacuum Corporation Model PMCS-2B water cooled, ultra-high vacuum diffusion pump using Convalex-10 fluid. The open cold trap was replaced with a Granville-Phillips Company 2-inch Cryosorb liquid nitrogen trap and an automatic level controller to keep the trap filled with liquid nitrogen. The Veeco vacuum gauge controller was replaced with a F. J. Cooke Company controller which automatically changed range, thus simplifying the electrical control system. A block diagram of the system is shown in Figure A-16. Figure A-17 shows the layout plan for the equipment in the racks on the launch pad.

For the prelaunch testing of SA-8, it was requested that monitoring be provided for the "LOX Bay" and "Fire Shield" areas of the S-I stage boattail for gaseous oxygen during LOX loading as well as monitoring for gaseous hydrogen and oxygen during tanking of the S-IV. Because only two sample inlet solenoid valves had been installed during rebuilding of the sample inlet manifold, an additional two-way solenoid valve was attached to one of the sample valves to enable the flow through this valve to be divided between either of the two areas within the S-I stage.

During previous propellant loading tests at KSC, consultation indicated that KSC desired to design and fabricate the electrical remote controls for the mass spectrometer in order to make such a system correspond to KSC practices and to be compatible with other KSC electrical systems. Because of this desire, the electrical controls were also redesigned by KSC as shown in the electrical block diagram in Figure A-18.

The remote controls rebuilt for the instrument system by KSC allowed complete restart, calibration, and operation to monitor the total gas environment of the interstage and boattail sampling points. The remote controls consisted of a local control panel, remote control of the vacuum gauge, remote control of the mass spectrometer, and remote recording of the pressure and mass spectrometer results. All controls were operated at a remote panel in the blockhouse of Complex 37 while the mass spectrometer system was located in the Manometer Room approximately 1700 feet away. In checking the system response time for the new lines, it was found that the flow through the very short (approximately 15 feet) S-I sampling lines as compared to the 175-foot lines to the S-IV stage created a pressure fluctuation within the analyzer. This was corrected by partially pinching down the S-I lines until the gas flow rates and pressures in all of the sampling lines were equal.

During the SA-8 tanking test, the HGDS was used to analyze for hydrogen, oxygen, nitrogen, and helium and to detect the water vapor level in both the first and second stages of the vehicle. During the tanking test, it was learned that the compartment inerting time for the S-I boattail was the same as the purging time for the S-IV/S-I interstage area as previously noted on the SA-9 tests. No gas leaks were detected in either stage. The response time for the sampling point inlets to the instrument was approximately 15 seconds.

Saturn I, SA-10

Between each successive tanking test, the remote controls and sampling system were developed and refined to provide a more reliable and controllable instrument which was capable of remote operation.

The HGDS was changed radically before the SA-10 tanking test. The basic instrument was replaced with a Model 21-614 Residual Gas Analyzer manufactured by the Consolidated Electrodynamics Corporation. The instrument was equipped with a Continuous Inlet System and an Automatic Peak Selector.

The peak selector allowed the pre-selection of up to six different gases for observation in a continuous cycle. This peak selector was modified by installing a resistor network across the channel pilot lights so a ramp signal indicating the channel observed could be remotely recorded. Relays allowed remote control of the automatic cycling and manual cycling. The 21-614 was modified so that the vacuum gauge controller automatically controlled the on-off switching of the filament depending on the vacuum observed by the vacuum gauge. The laboratory operational capability of the instrument was not impaired by these modifications.

The vacuum equipment was installed in a 51-inch high sloping front rack. The 21-614 sat on top of this rack (Fig. A-19) in its own cabinet. A rear view (Fig. A-20) shows the actual layout of the equipment within the two portable racks.

The vacuum system was rearranged and simplified to remove unnecessary controls and valves. With this instrumentation, a more accurate and versatile system was possible. A single gas could be monitored continuously, or six different gases could be monitored on a 2-minute cycle from any one of the sample points.

During the tanking test, the monitor was used again to observe the concentration of various gases within the S-I/S-IV interstage area and two discrete locations within the S-I boattail. Through the use of the remote controls, the instrument was calibrated at frequent intervals for hydrogen, nitrogen, oxygen, and helium using pre-analyzed standard gas. The launch vehicle then could be monitored for these same gases both qualitatively and quantitatively. The response time was about 20 seconds with 1/4-inch tubing with the peak selector operating in a cyclic mode of operation.

No hydrogen leaks were detected in the S-1/S-IVB interstage during the tanking and detanking of LH_2. No oxygen leaks were detected within the S-I boattail. The change from air to GN_2 purge and GN_2 back to air was observed during the test. One of the S-I sample points indicated about one percent oxygen present when the GN_2 purge was in use. However, no alarm was caused since the functions recorded for this sampling point were unusual and erratic enough to indicate faulty operation of the sampling line. After the test, this evaluation was confirmed when a loose pressure cap was found on a "T" connection in the sample line between the Manometer Room and the swing arm. This sample line had been previously pressure tested for leaks during tubing installation and the cap had not been tightened properly.

Saturn IB, AS-201

The HGDS was repackaged into a single 56-inch high cabinet and moved to Complex 34 to be used during tanking tests of AS-201. Figures A-21 and A-22 show the instrument configuration. No changes in the instrument system or electrical controls were made. However, only a single sample probe was installed in the interstage of the S-IVB which provided sampling to the instrument. No other areas were sampled on AS-201 during the first tanking test.

The system was operated in support of a manual LOX loading test of the S-IVB facility vehicle, the S-IVB automatic LOX and manual LH_2 facility checkout loading, and the S-IVB automatic LOX and automatic LH_2 facility checkout loading.

Some electronic difficulties were encountered during the first two tests which were remedied before the third test. It was found that the S-IVB interstage compartment of the Saturn IB (a larger volume than on the Saturn I) also was purged with GN_2 to less than one percent oxygen in approximately six minutes.

During the post-test evaluation, it was determined that a few improvements to the vacuum system were required to fully provide HGDS service to the Saturn IB configuration. The sample inlet manifold was changed from the four 115 Vac solenoid valves on a tubing "T" fitting manifold to six Marotta 28 Vdc valves. The ionization gauge controller was changed to a Granville-Phillips Company Model 02 with solid state circuitry; however, due to delivery problems, a Model 01 controller was used temporarily. The liquid nitrogen level controller was changed to a Cryogenics, Incorporated "LN_2 Cryotrol." A water pressure drop-out switch was connected to the water line serving the diffusion pump to protect it in the event of a water pressure failure, and a water pressure regulator was added to control water pressure. A thermocouple gauge controller with an automatic relay also was attached to the system. A vacuum gauge tube sensed the fore pump pressure to shut off the diffusion pump in case of a drive belt failure or other failure of the fore pump.

The system was used for support of CDDT on AS-201. Sample lines were installed in the S-IB engine compartment, the S-IVB aft interstage, and the Instrument Unit (IU).

During the first CDDT, the equipment functioned very satisfactorily. During the Environmental Control System change from air to GN_2 just prior to LH_2 loading, the instrument detected a momentary failure of the GN_2 purge to the S-IVB interstage. During the actual LH_2 loading sequence, a gaseous helium purge to the S-IVB engine was detected. The concentration of helium in the nitrogen-purged compartment was about one percent. The capability to detect these slight changes in the Environmental Control System and the detection of the helium purge indicated that the HGDS functioned properly and could accomplish its mission to detect hazardous gases.

Gaseous helium was not detected in either the S-IB or the IU during the CDDT. No hydrogen or oxygen leaks were detected during the test. The test was terminated at T-3:20 due to launch pad facility problems.

On the second CDDT, the equipment operated marginally until the completion of LOX loading on the S-IB and then failed. Failure was due to a malfunction of a vacuum gauge tube. In an attempt to consolidate the system further, a General Electric Model 22GT102 miniature ionization gauge tube was installed in the instrument. It was found that the General Electric tube was not rugged enough due to miniaturization to withstand the HGDS environment, and, therefore, the vacuum sensor was replaced with the original type large geometry ionization gauge tube.

The instrument was operated during launch of AS-201 to determine its capability to withstand the shocks encountered during lift-off. Careful examination of the instrument after launch indicated no physical or electrical damage to the unit as a result of lift-off.

Slight variations in the vacuum system pressure were also observed, and the need for an unvarying pressure within the vacuum system was necessary for accurate analyses. It was decided to install an automatic pressure controller which would sense variations in the vacuum system pressure and automatically adjust the sample inlet flow to compensate for this variation. Micrometer needle valves in the sample lines allowed gross adjustment of sample inlet flow, and the automatic controller provided automatic fine adjustment as required. The sample inlet valve manifold was changed from tubing "T" fittings to a series of six self-manifolding solenoid valves. More valves can be added to such a manifold by merely bolting them to the end valve in the manifold. The manifold assembly is shown in Figure A-23.

The operation of the diffusion pump was completely automated. The vacuum gauge which senses the fore line pressure operated the diffusion pump through a pressure-actuated relay. When the fore line pressure is at the proper level for the diffusion pump to operate, the diffusion pump is automatically actuated.

As a result of this successful development program and the launch schedule of the Apollo Saturn IB, it was decided that permanent HGD Systems would be assembled at MSFC. Therefore, the prototype was repackaged to conform to the best manufacturing procedures, ease of handling, and reliability. Figures 1 and 2 in the main body of this report show the final configurations of the HGDS installed on Complex 34 and Complex 37B. In addition to these two units, a third system was assembled to provide gas surveillance for the Saturn V 500-F facilities test vehicle. While this unit was identical to the HGDS provided for the Saturn IB, the control system for it was designed so that the analyzer would be operated by the ground computers and read out through the digital data acquisition system. The distance from the launch pad area to the launch control center for the Saturn V is about 2-1/2 miles, so direct control and readout were not practical.

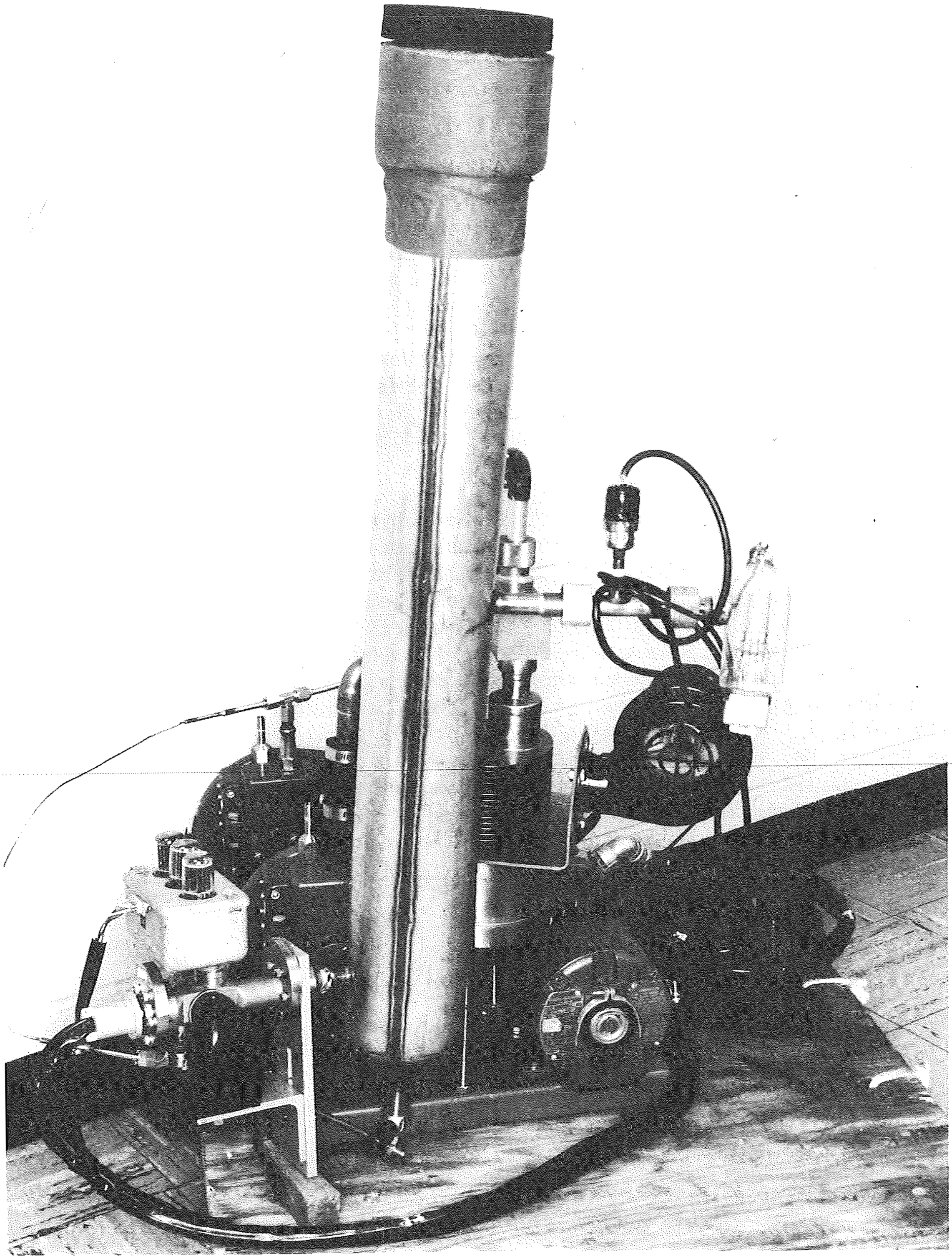

FIGURE A-1. - HAZARDOUS GAS DETECTOR, SATURN I, SA-7

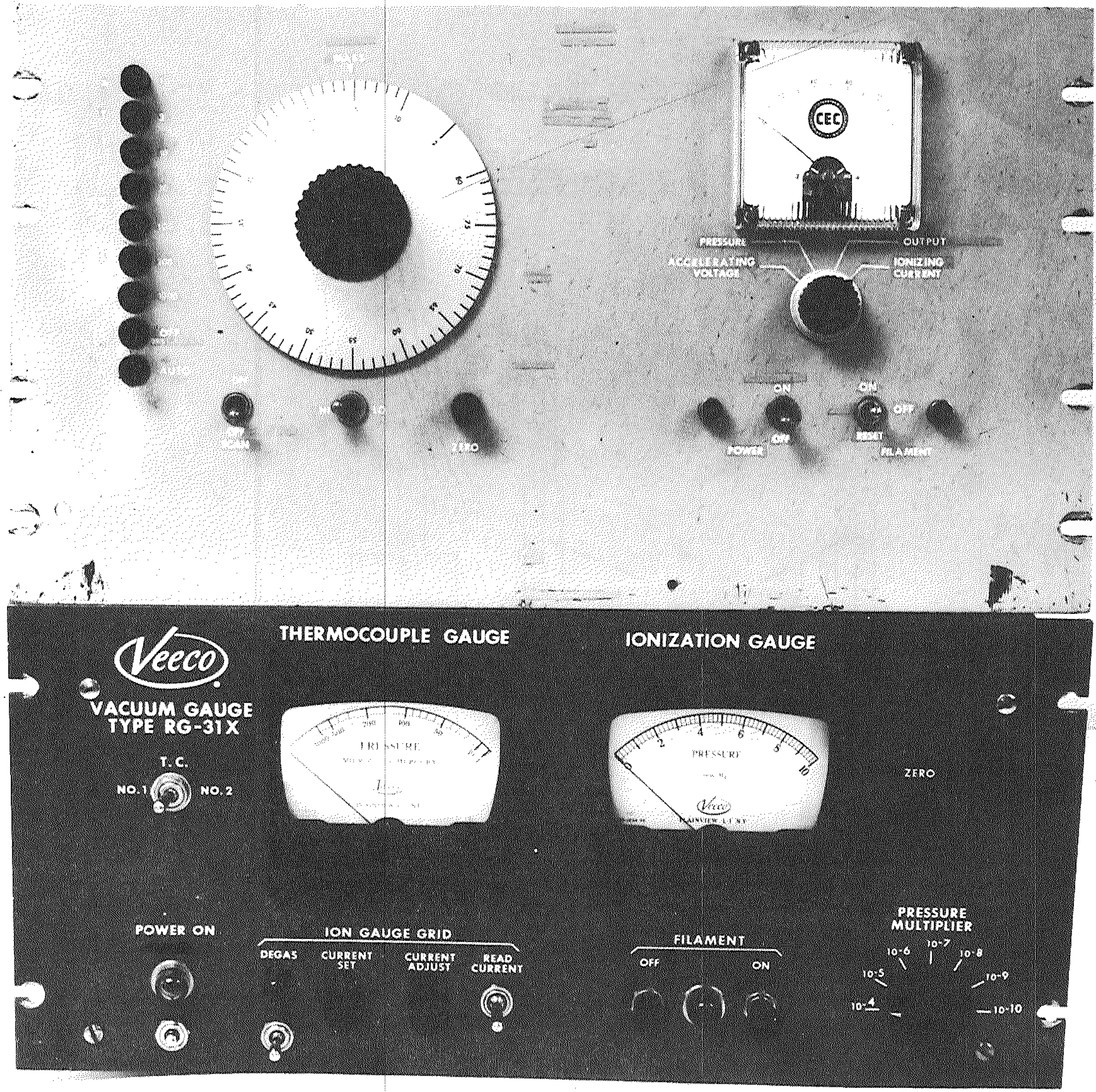

FIGURE A-2. - HAZARDOUS GAS DETECTOR, DIATRON AND VACUUM GAUGE CONTROLS, SA-7

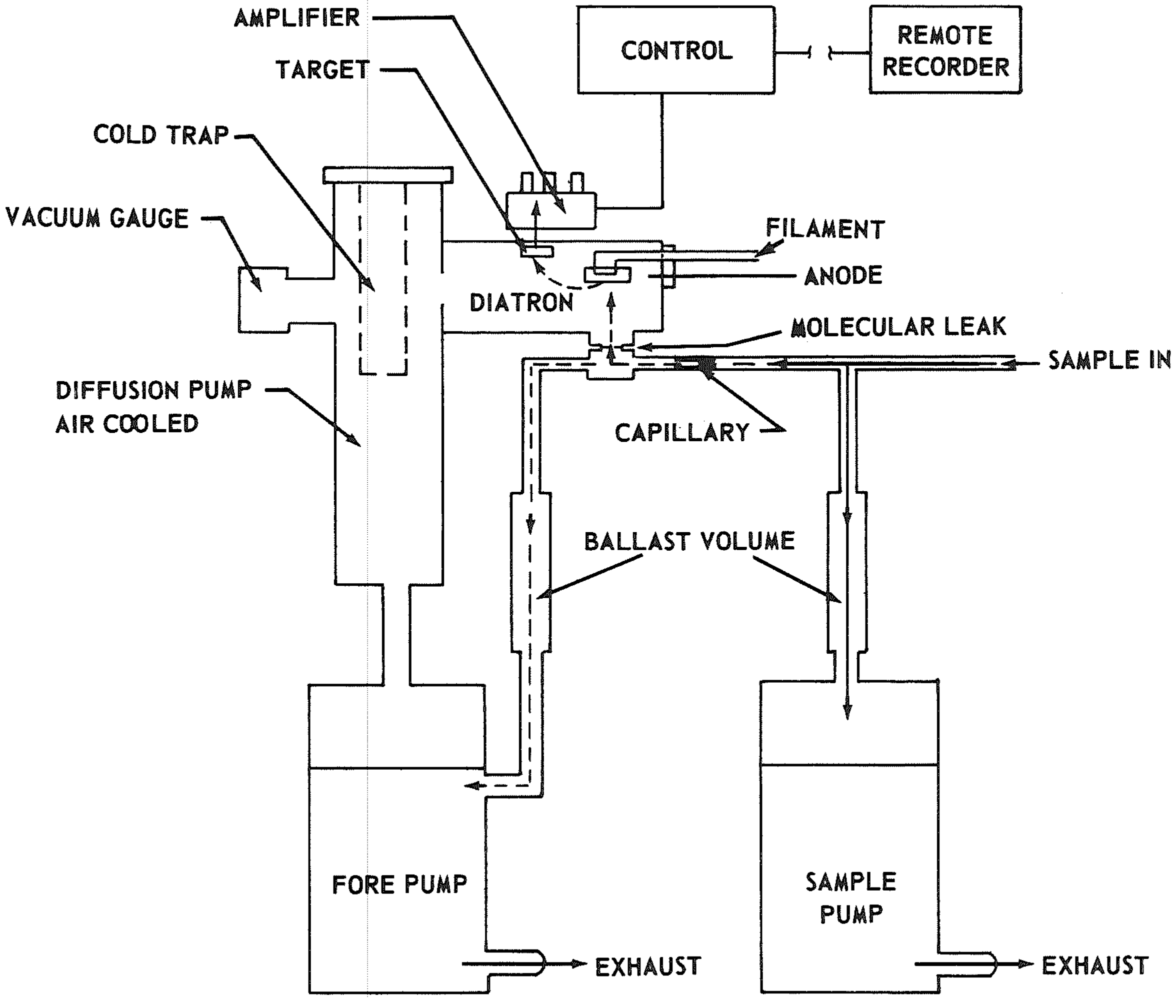

FIGURE A-3. - HAZARDOUS GAS MONITOR PICTORIAL DIAGRAM, SA-7, SA-9

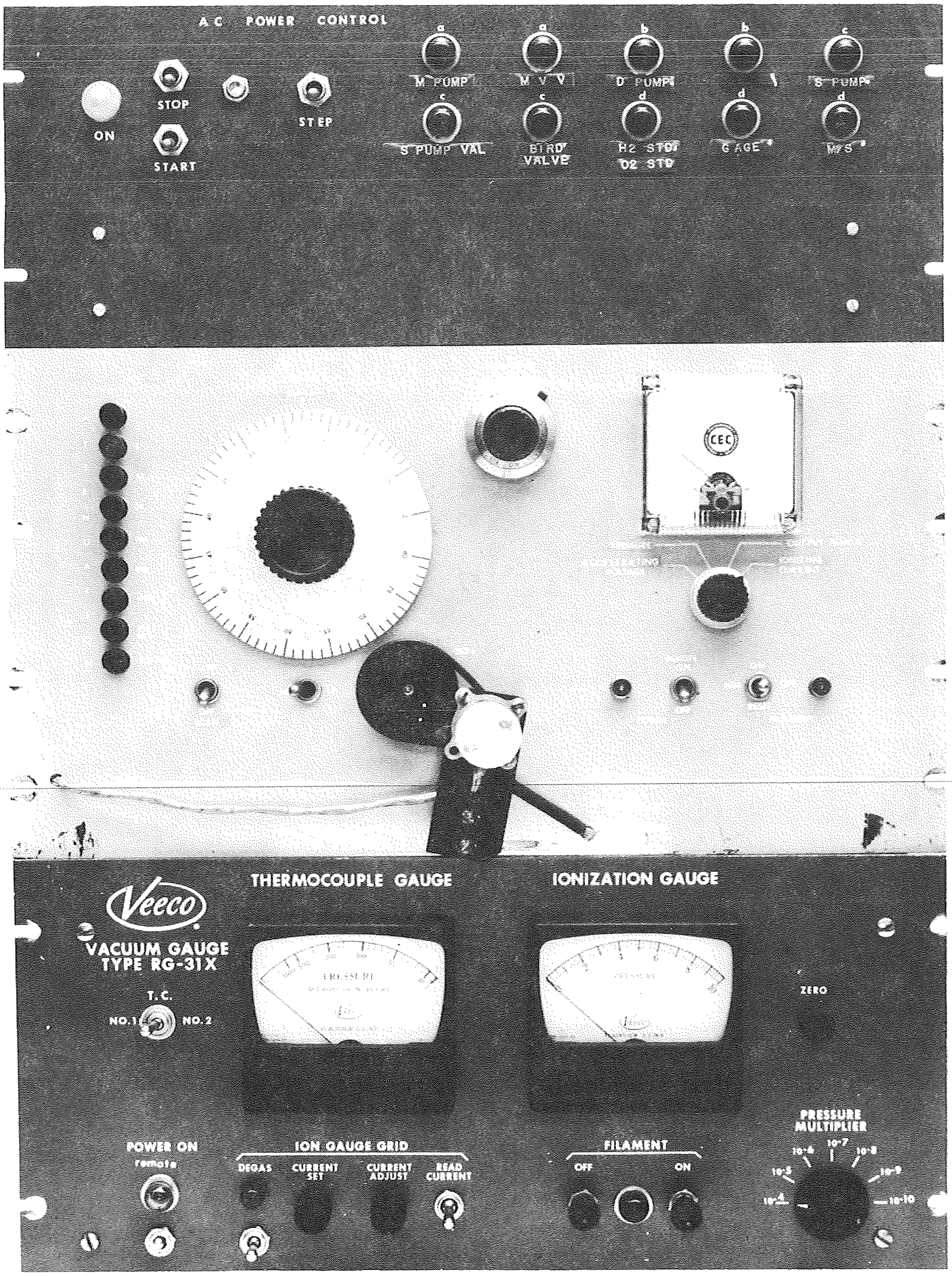

FIGURE A-4. - HAZARDOUS GAS DETECTOR, LOCAL CONTROL PANELS, SA-9

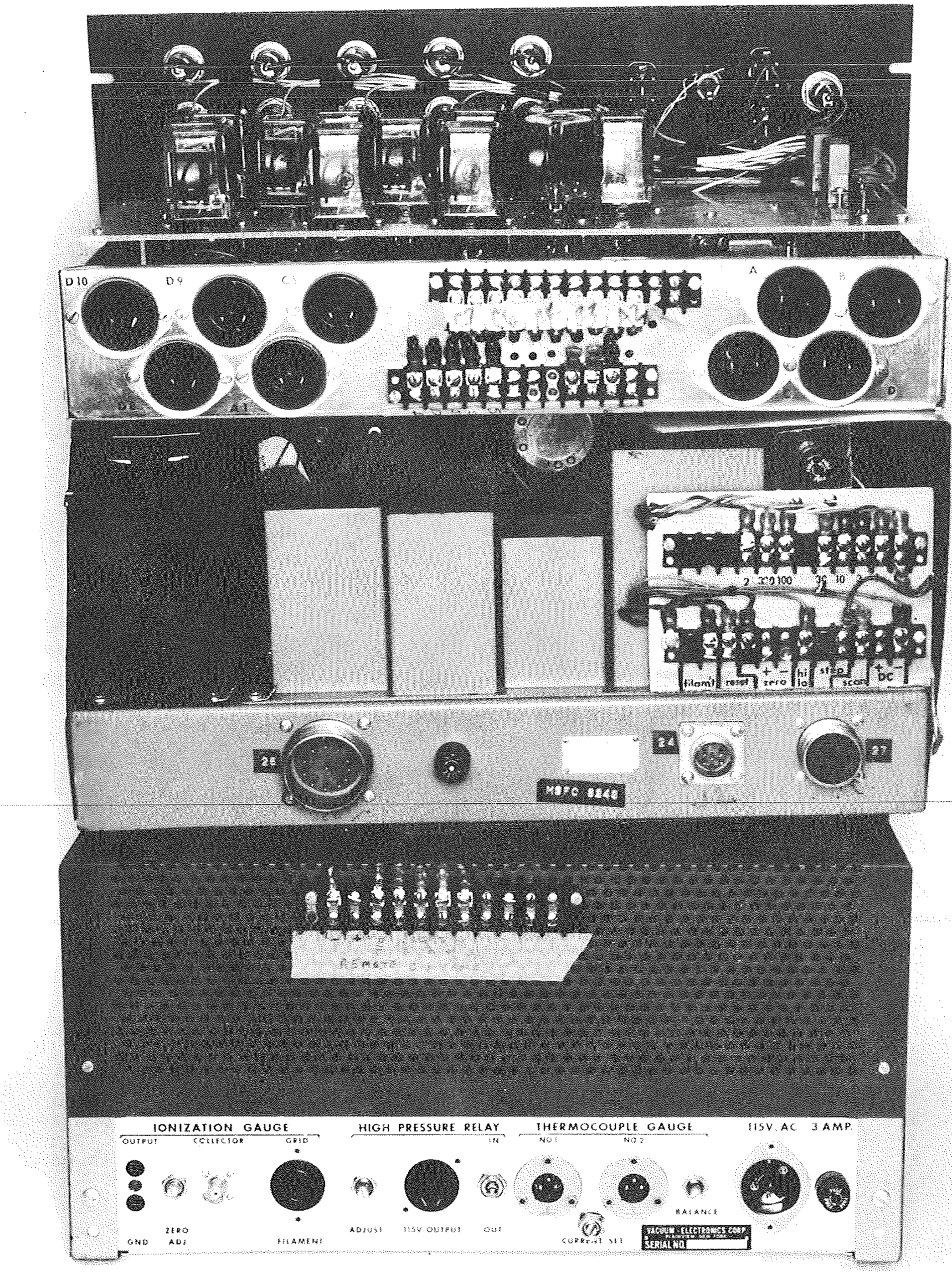

FIGURE A-5. - HAZARDOUS GAS DETECTOR, LOCAL CONTROL PANELS (REAR), SA-9

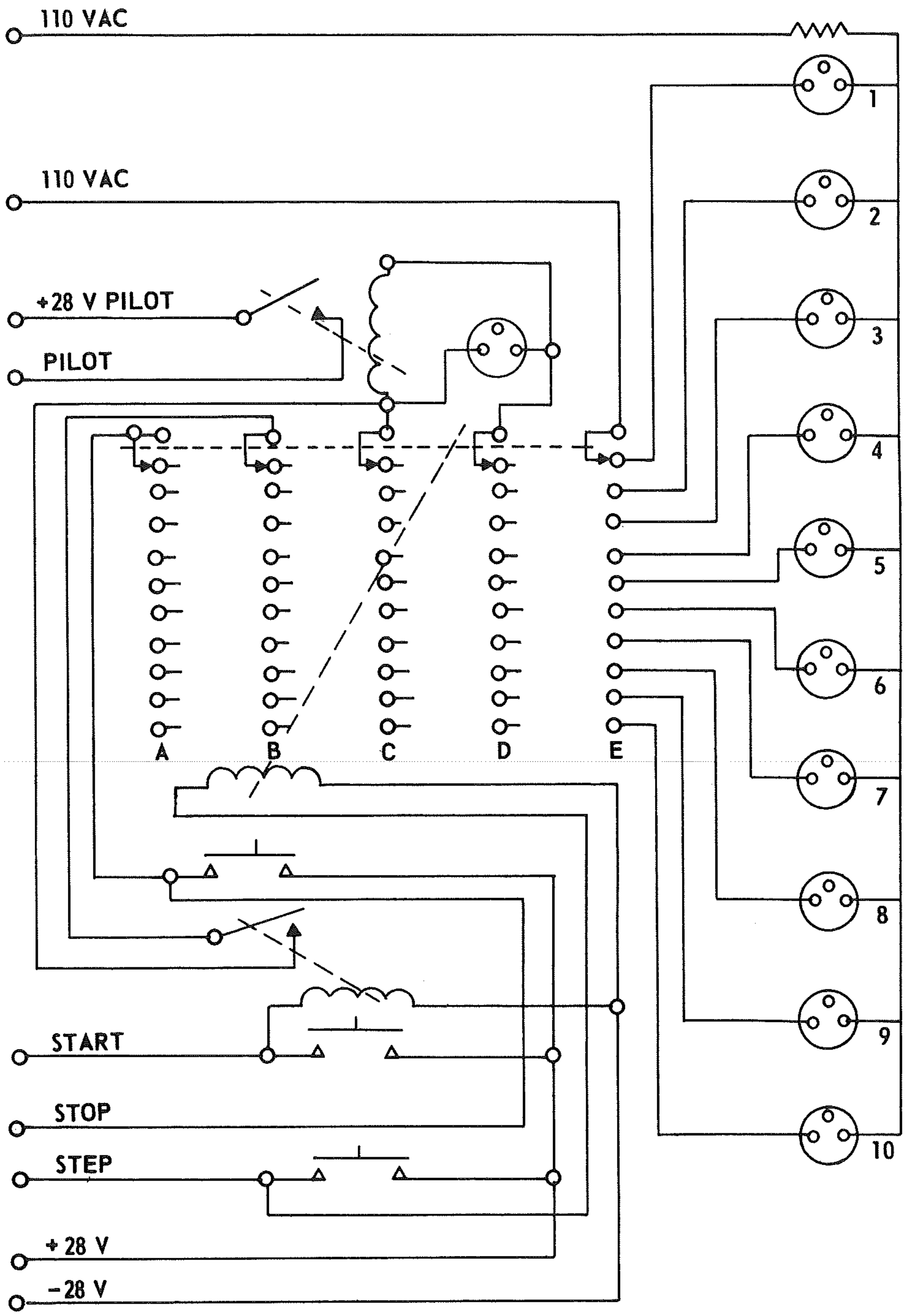

FIGURE A-6. - LOCAL POWER CONTROL

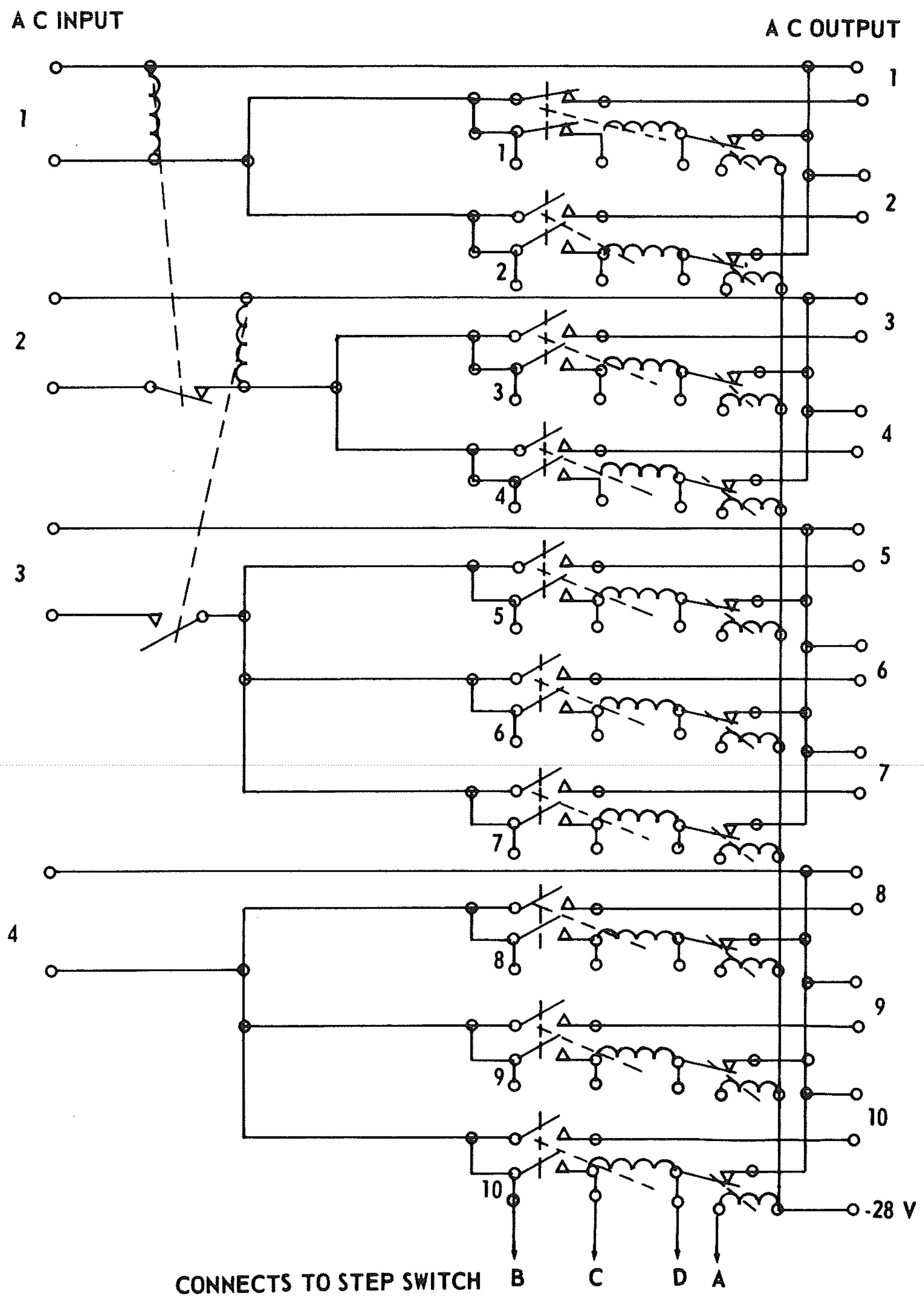

FIGURE A-7. - LOCAL POWER CONTROL

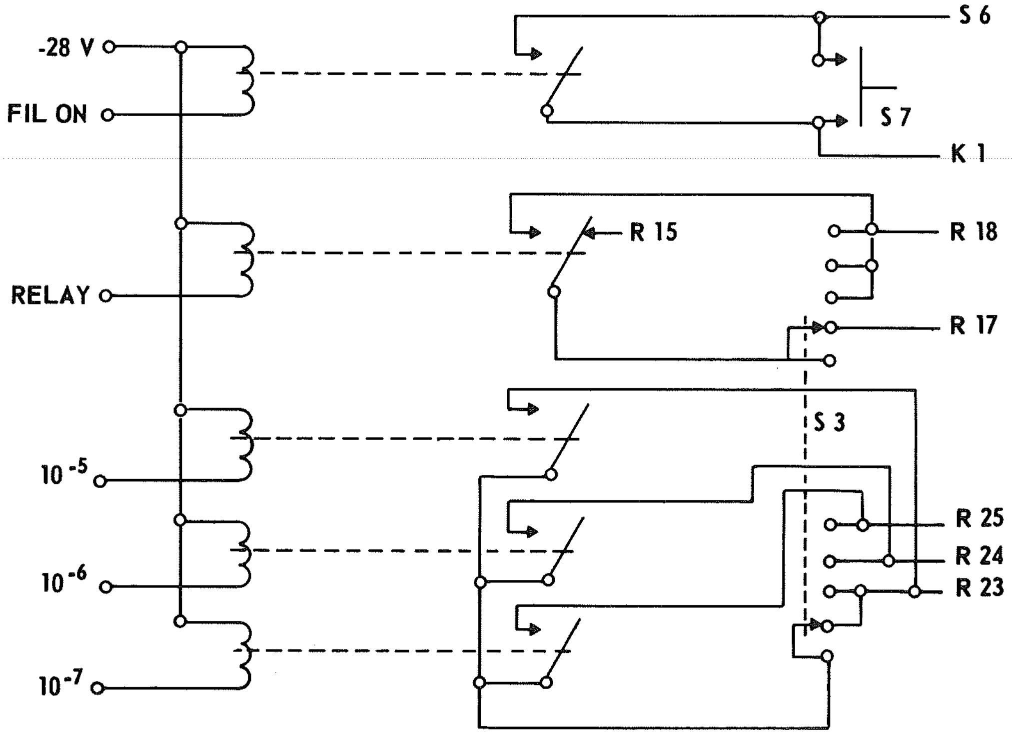

FIGURE A-8. - MODIFICATION OF VEECO VACUUM GAUGE FOR REMOTE CONTROL

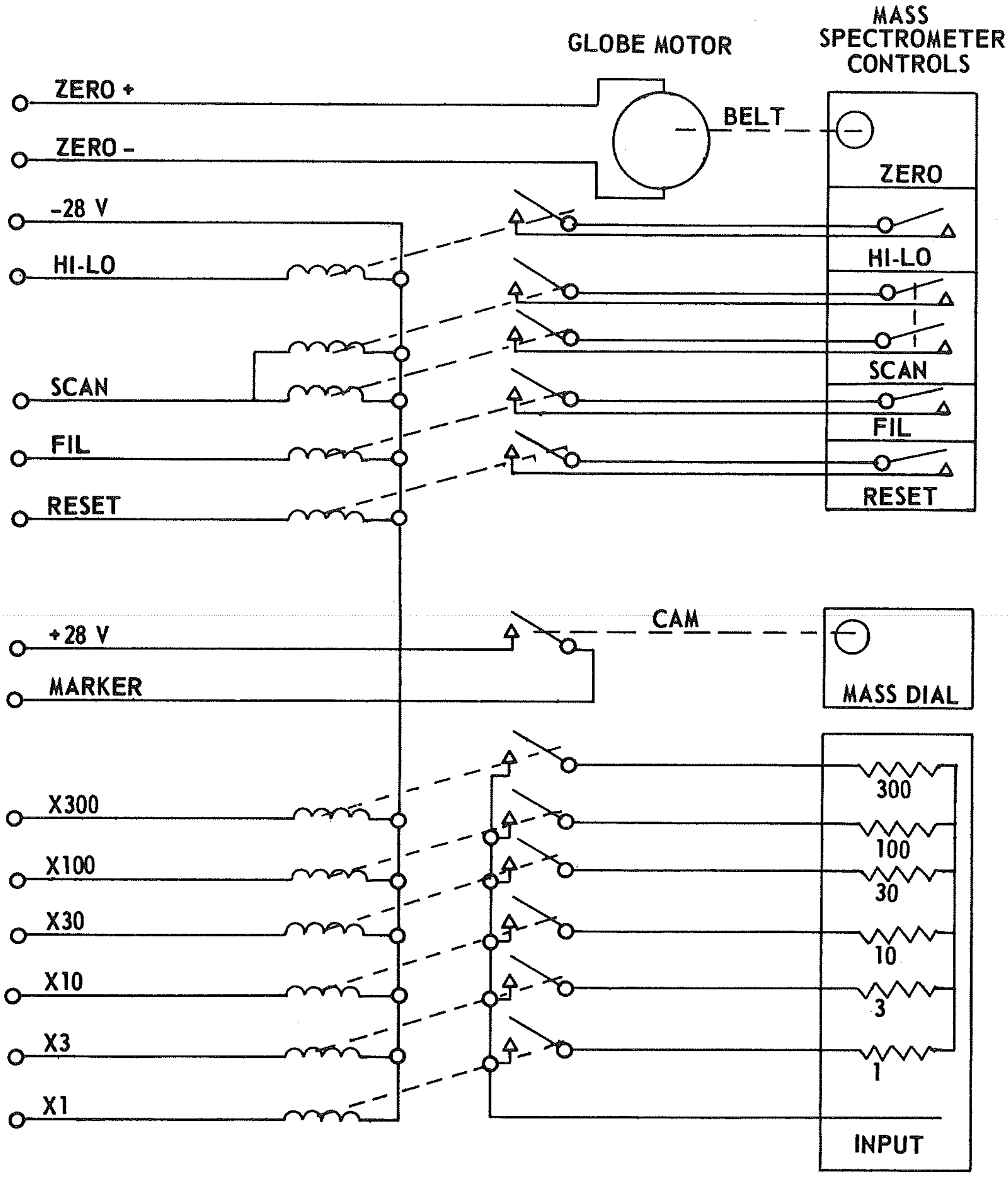

FIGURE A-9. - MODIFICATION OF CEC 21-612 MASS SPECTROMETER FOR REMOTE CONTROL

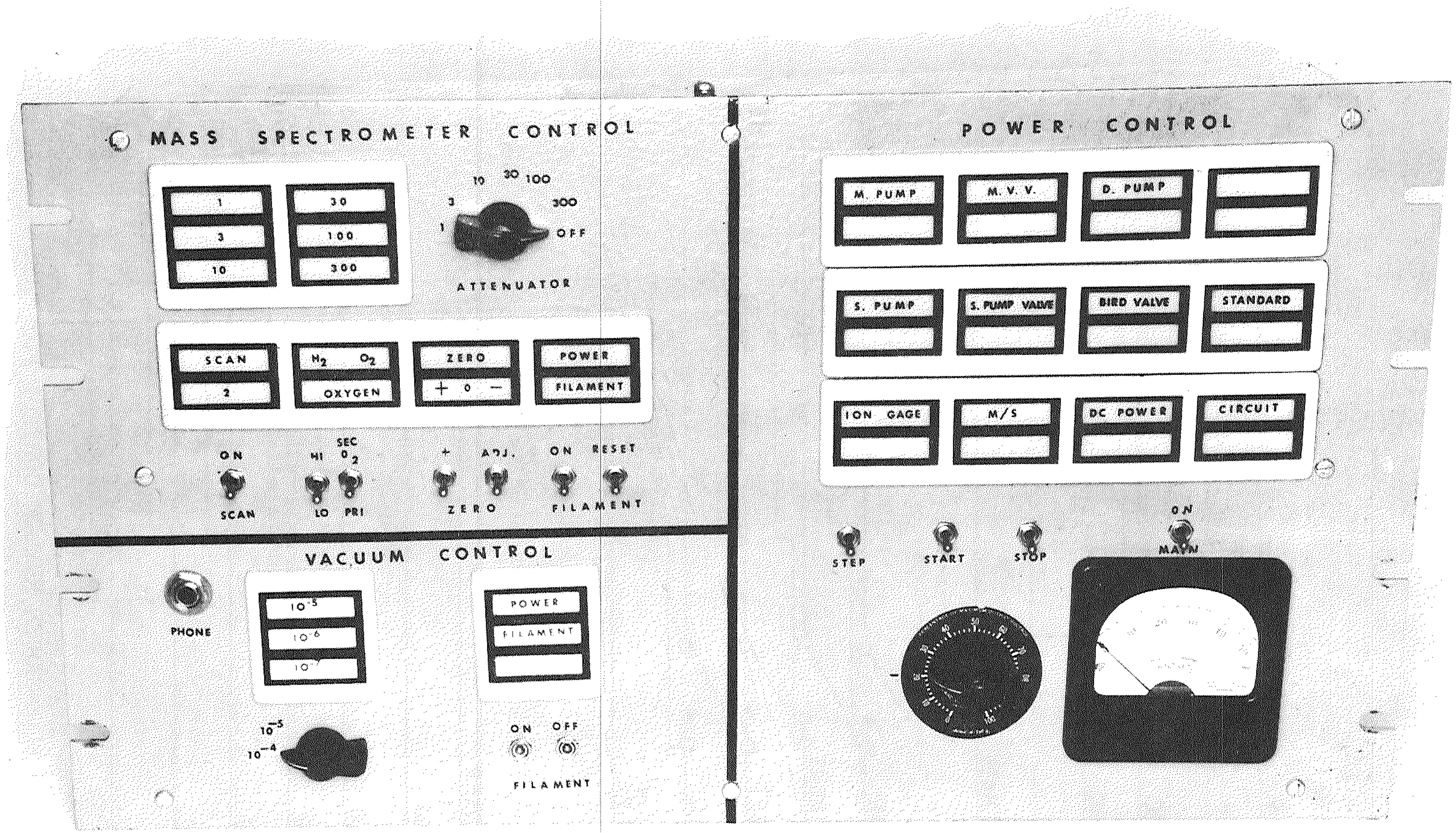

FIGURE A-10. - HAZARDOUS GAS DETECTOR BLOCKHOUSE REMOTE CONTROL, SA-9

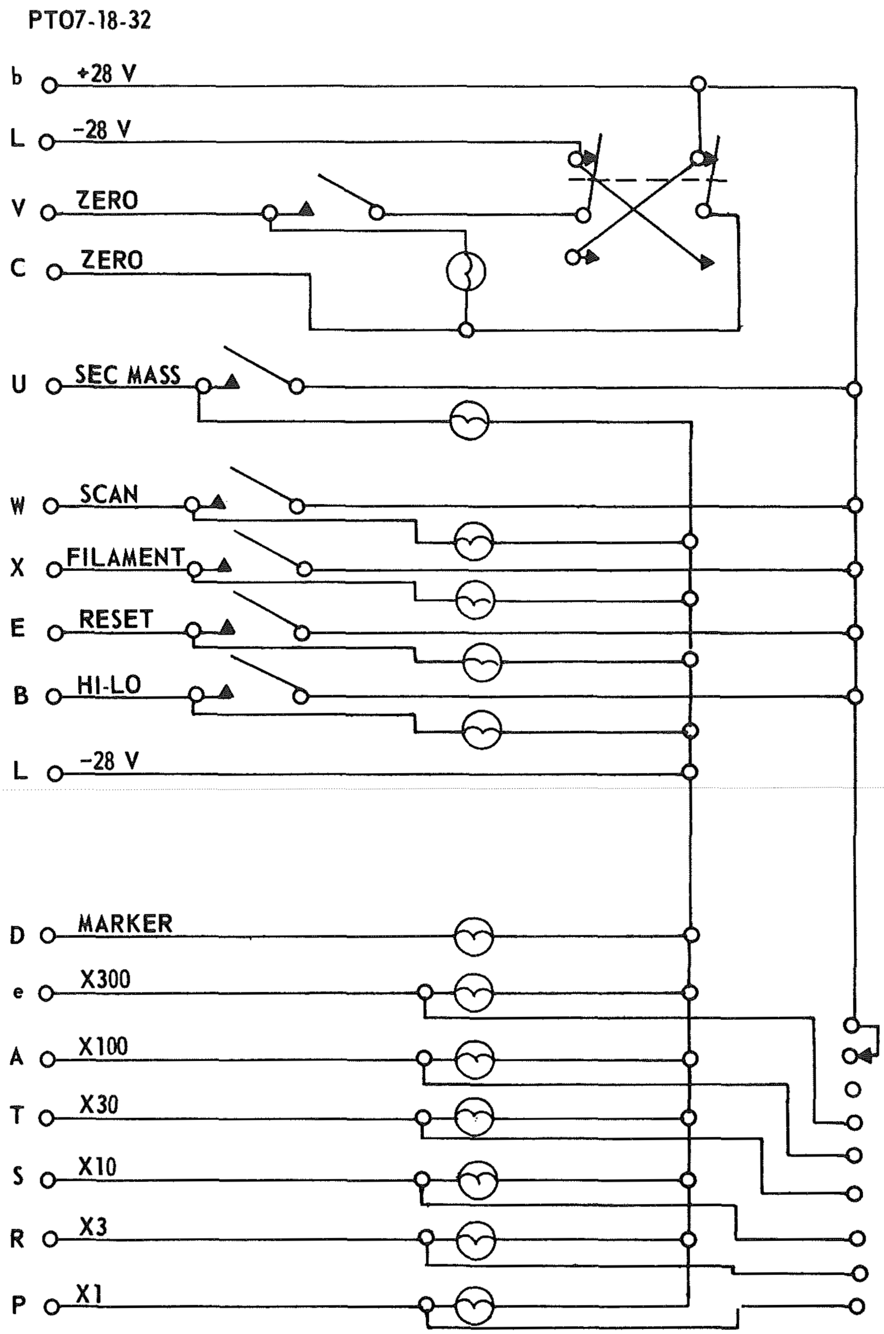

FIGURE A-11. - BLOCKHOUSE REMOTE CONTROL FOR MASS SPECTROMETER

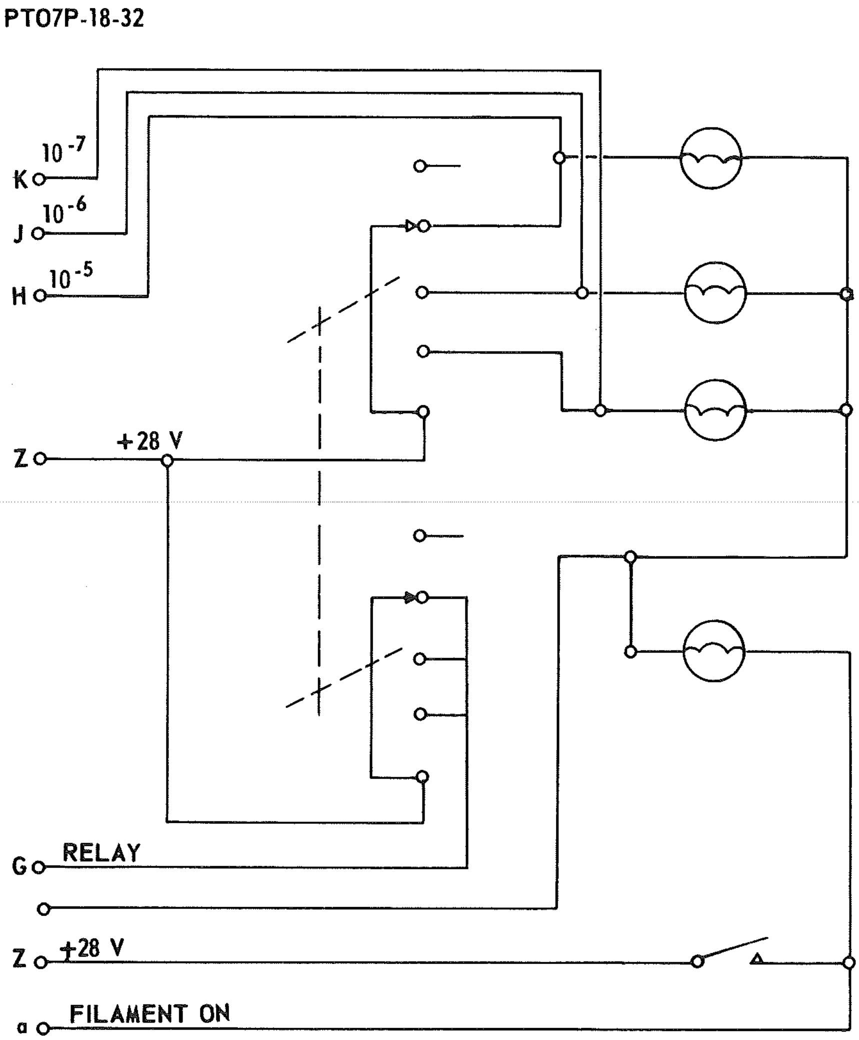

FIGURE A-12. - BLOCKHOUSE REMOTE CONTROL FOR VACUUM GAUGE

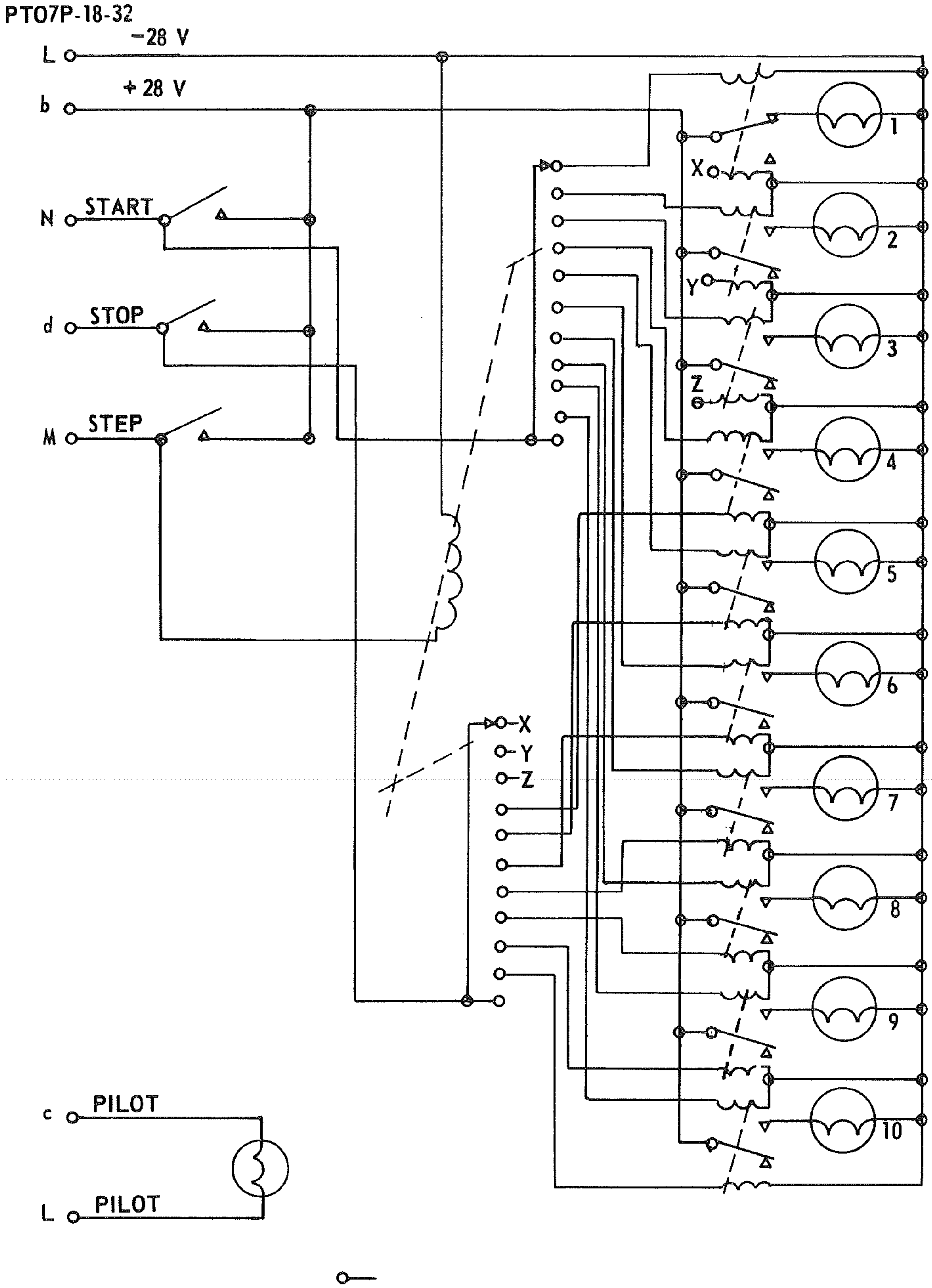

FIGURE A-13. - BLOCKHOUSE REMOTE CONTROL FOR ac POWER

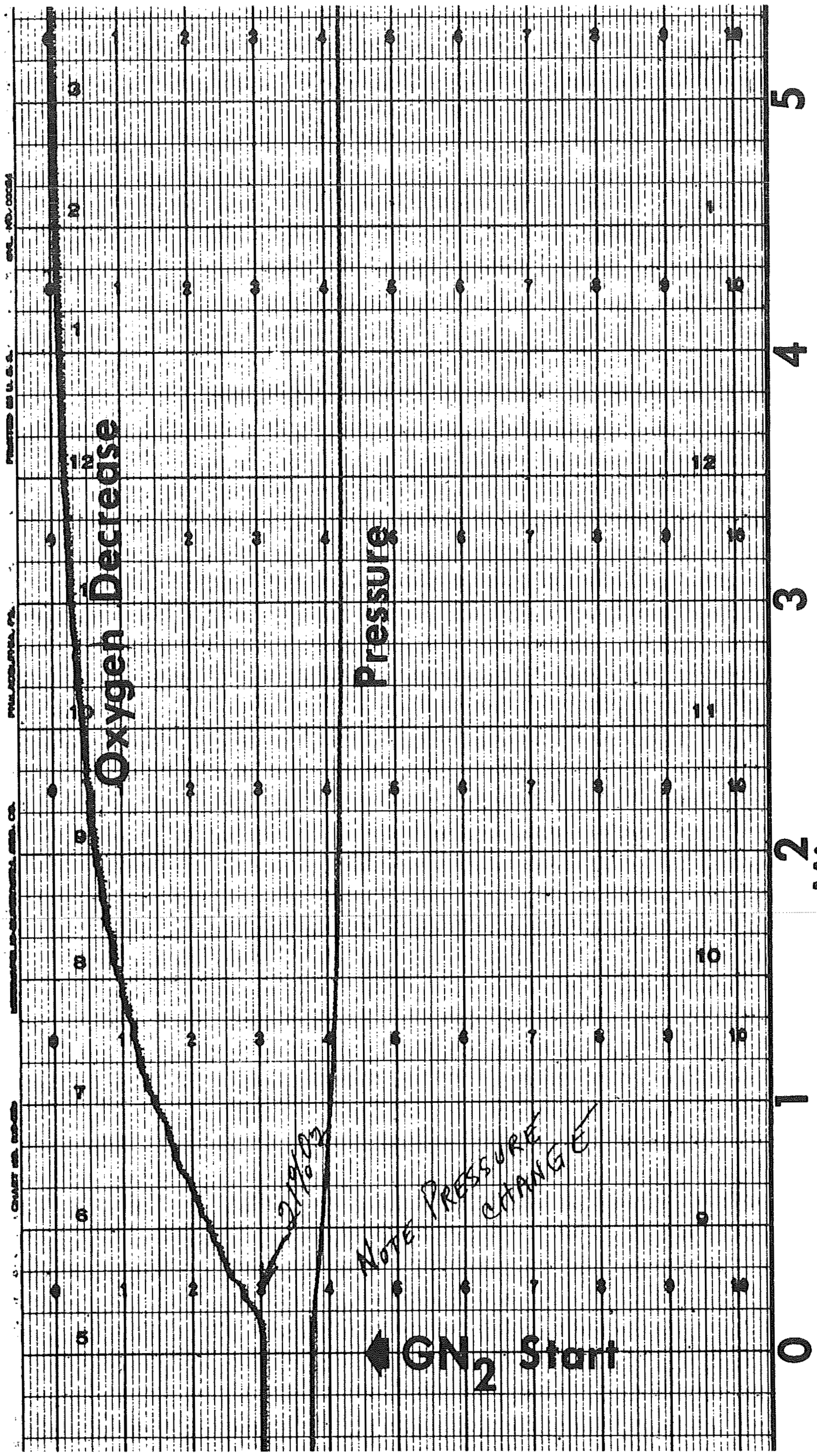

FIGURE A-14. - GASEOUS NITROGEN PURGE OF S-IV AFT, SA-9

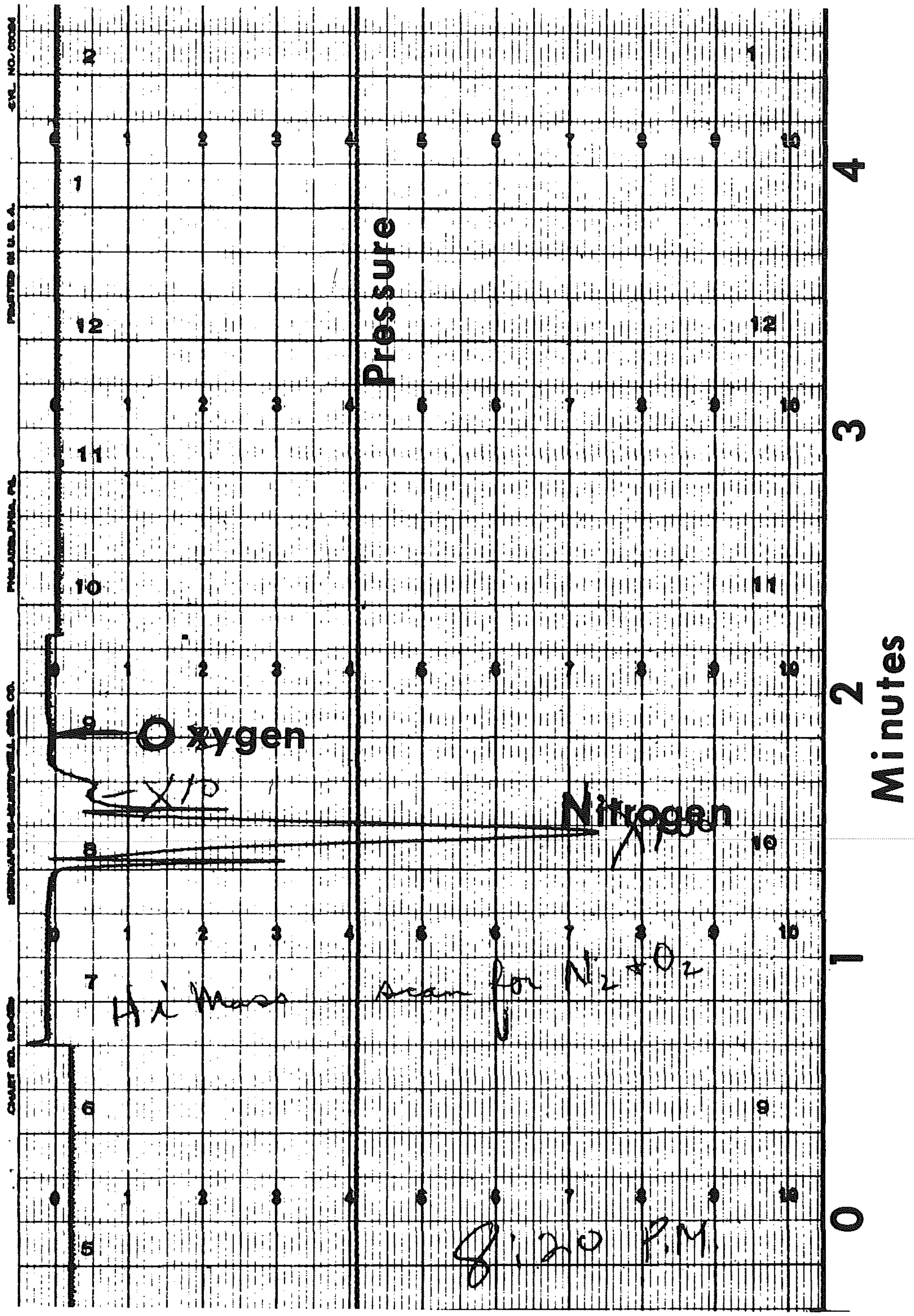

FIGURE A-15. - PROOF OF OXYGEN REMOVAL BY GASEOUS NITROGEN PURGE

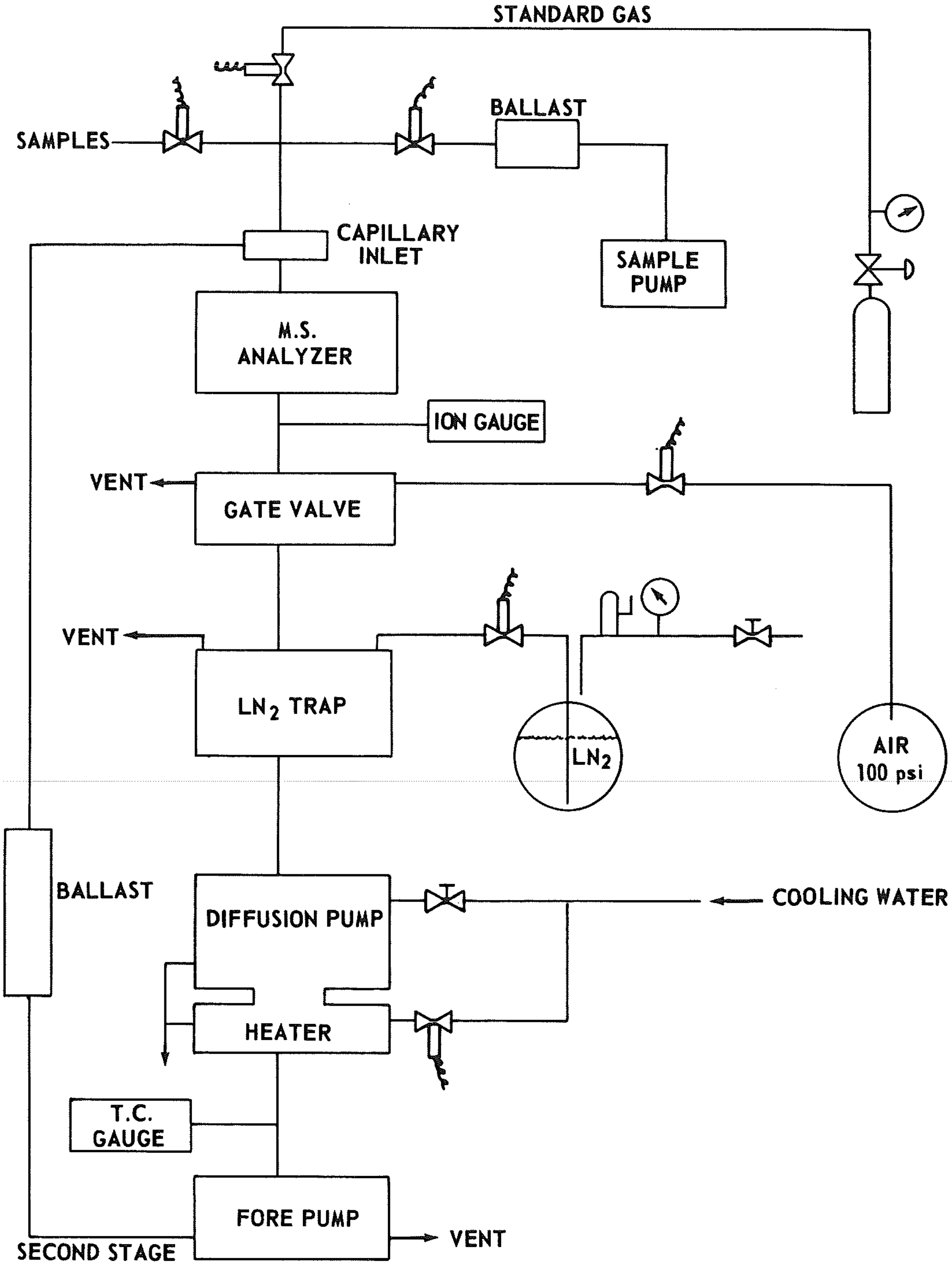

FIGURE A-16. - HGDS MECHANICAL BLOCK DIAGRAM

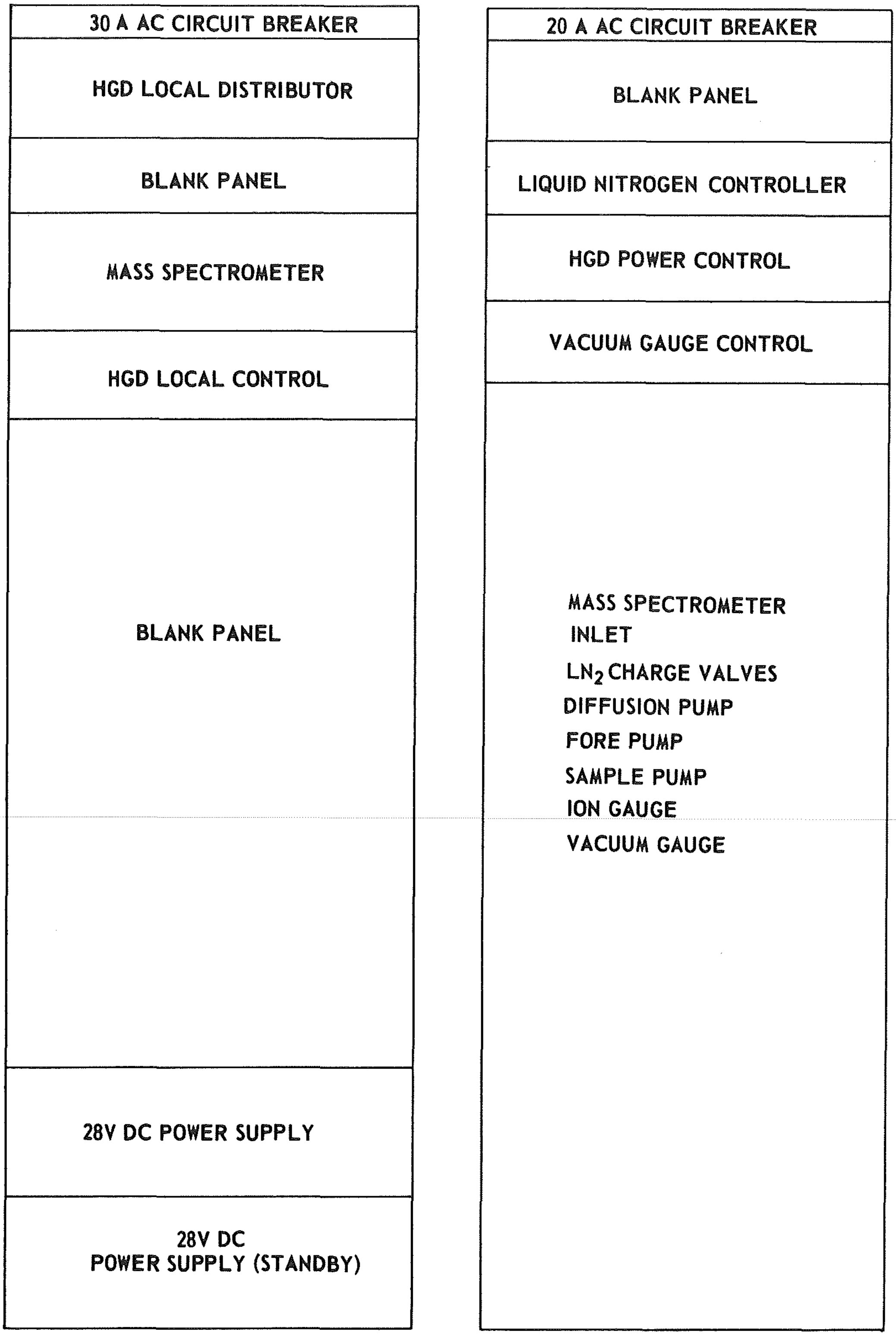

FIGURE A-17. - LAUNCH PAD RACK PANEL LAYOUT

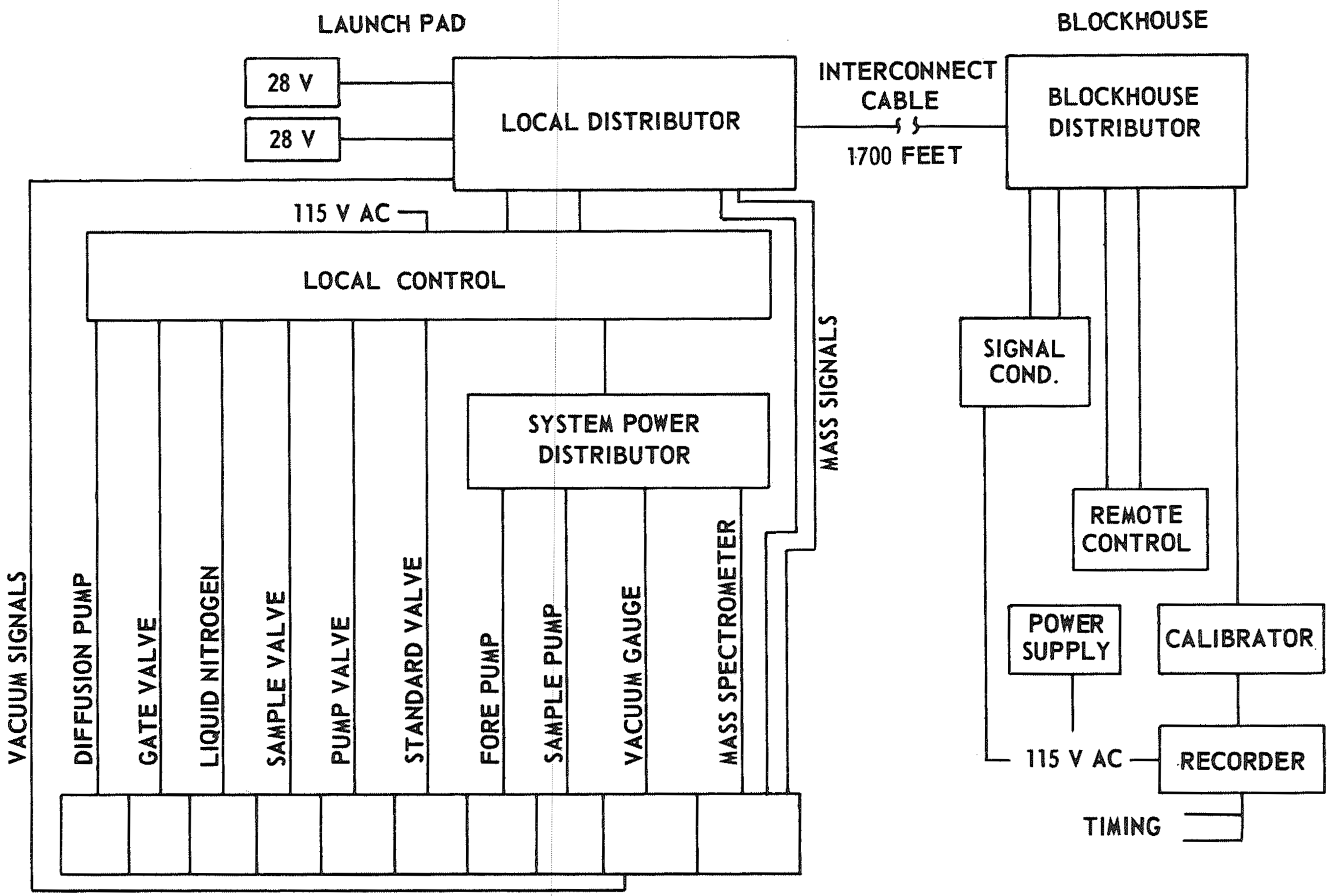

FIGURE A-18. - ELECTRICAL BLOCK DIAGRAM

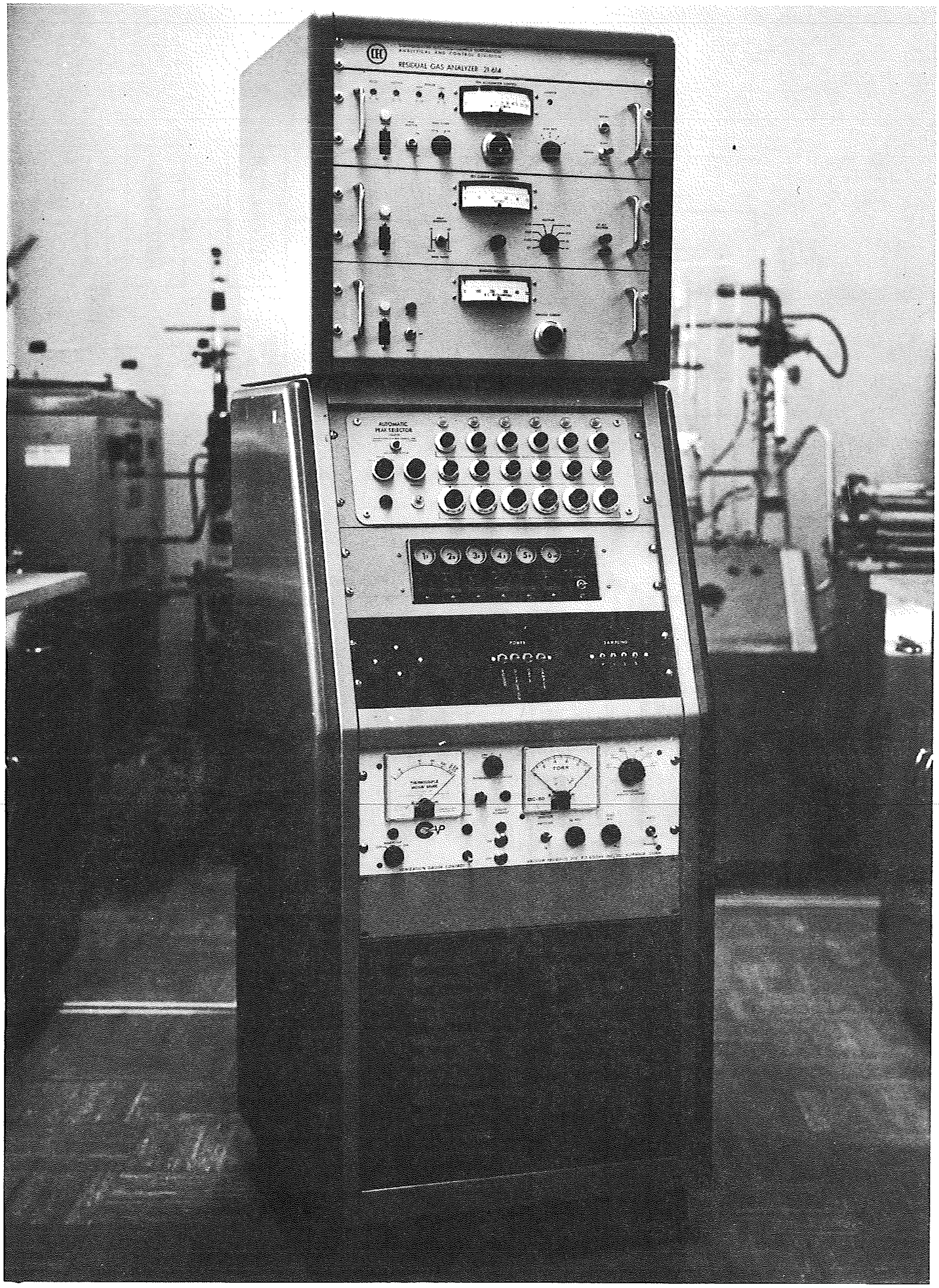

FIGURE A-19. - HAZARDOUS GAS DETECTOR, SA-10

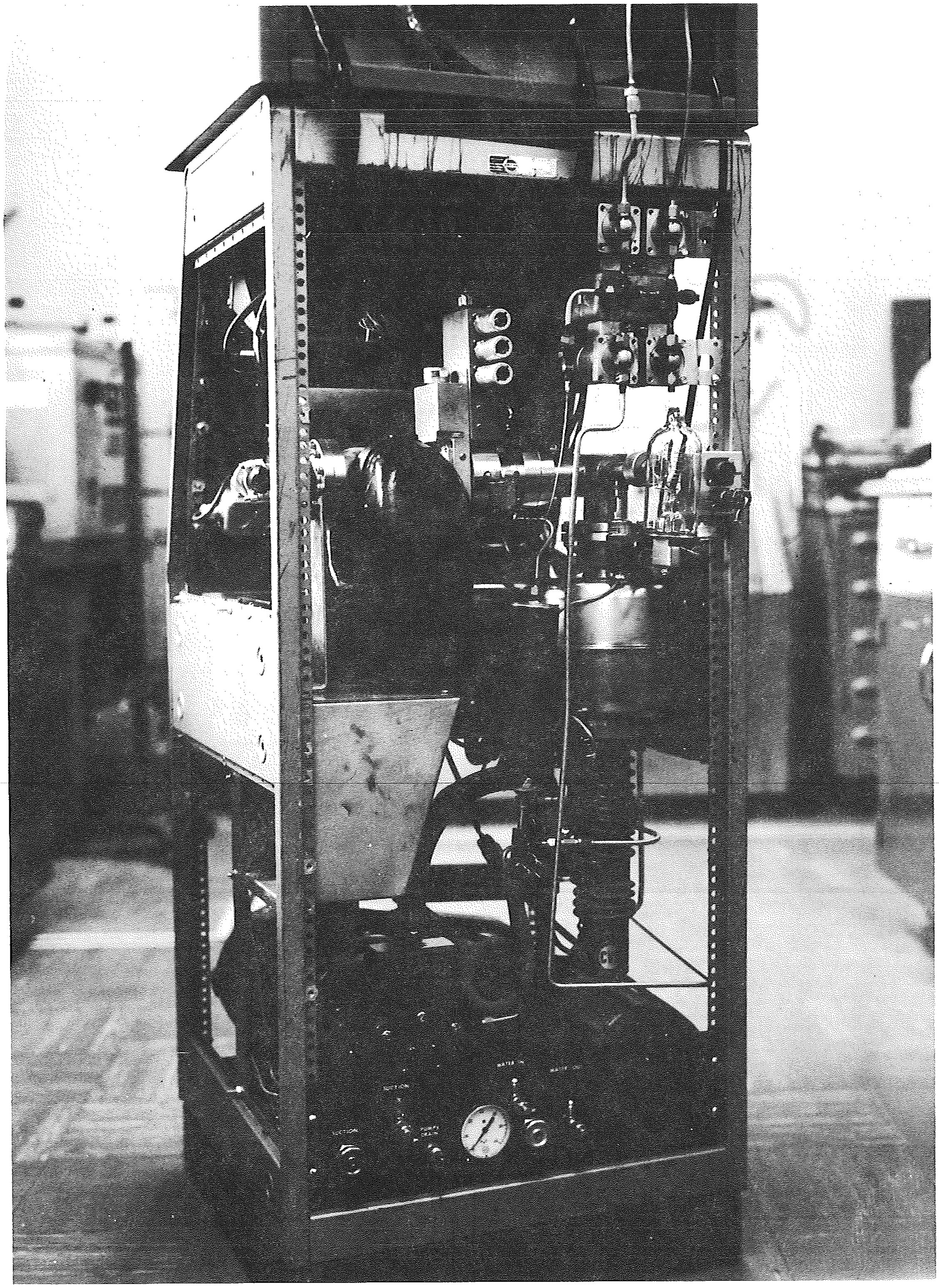

FIGURE A-20. - HAZARDOUS GAS DETECTOR, REAR VIEW

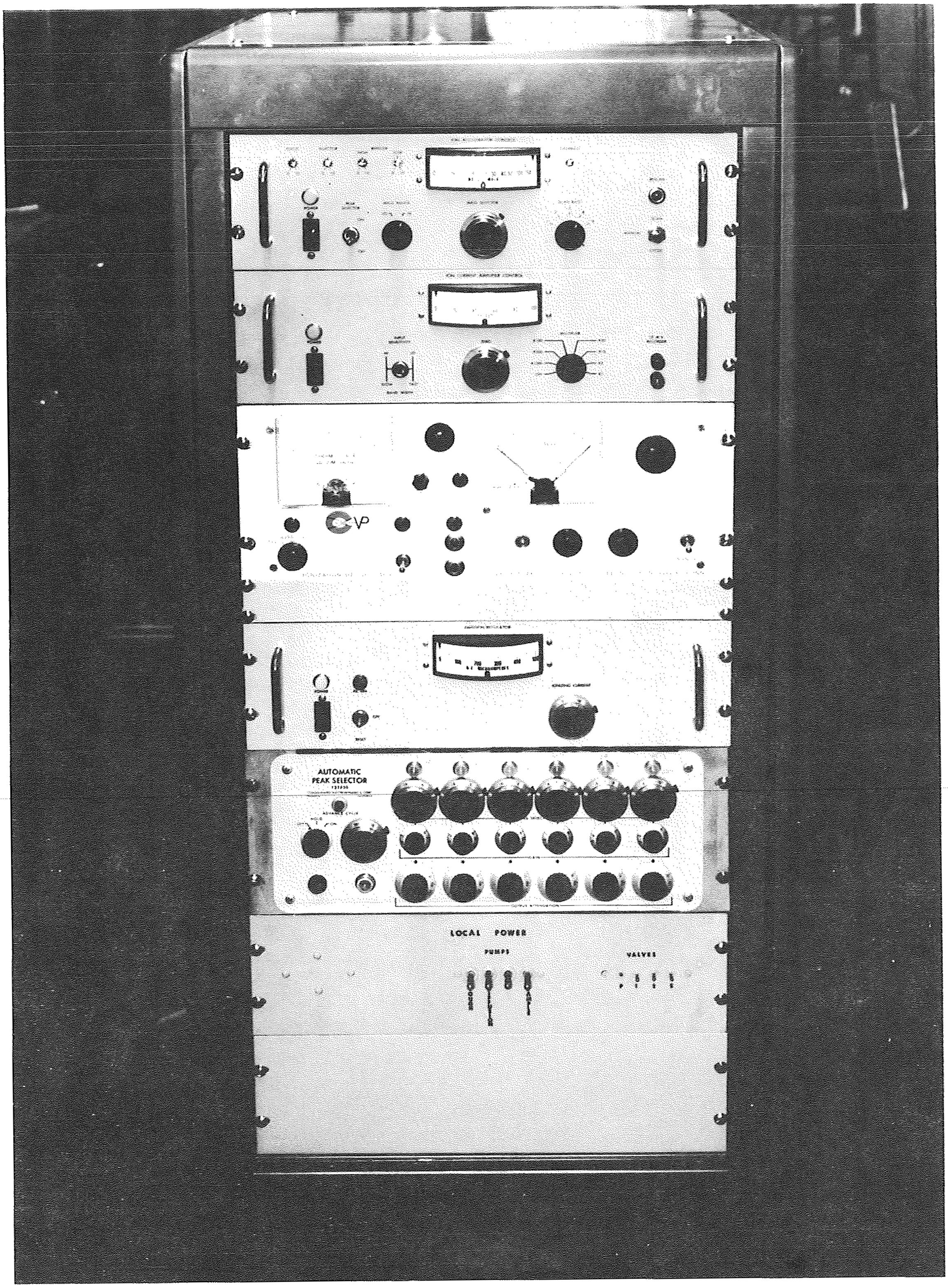

FIGURE A-21. - HAZARDOUS GAS DETECTOR, AS-201

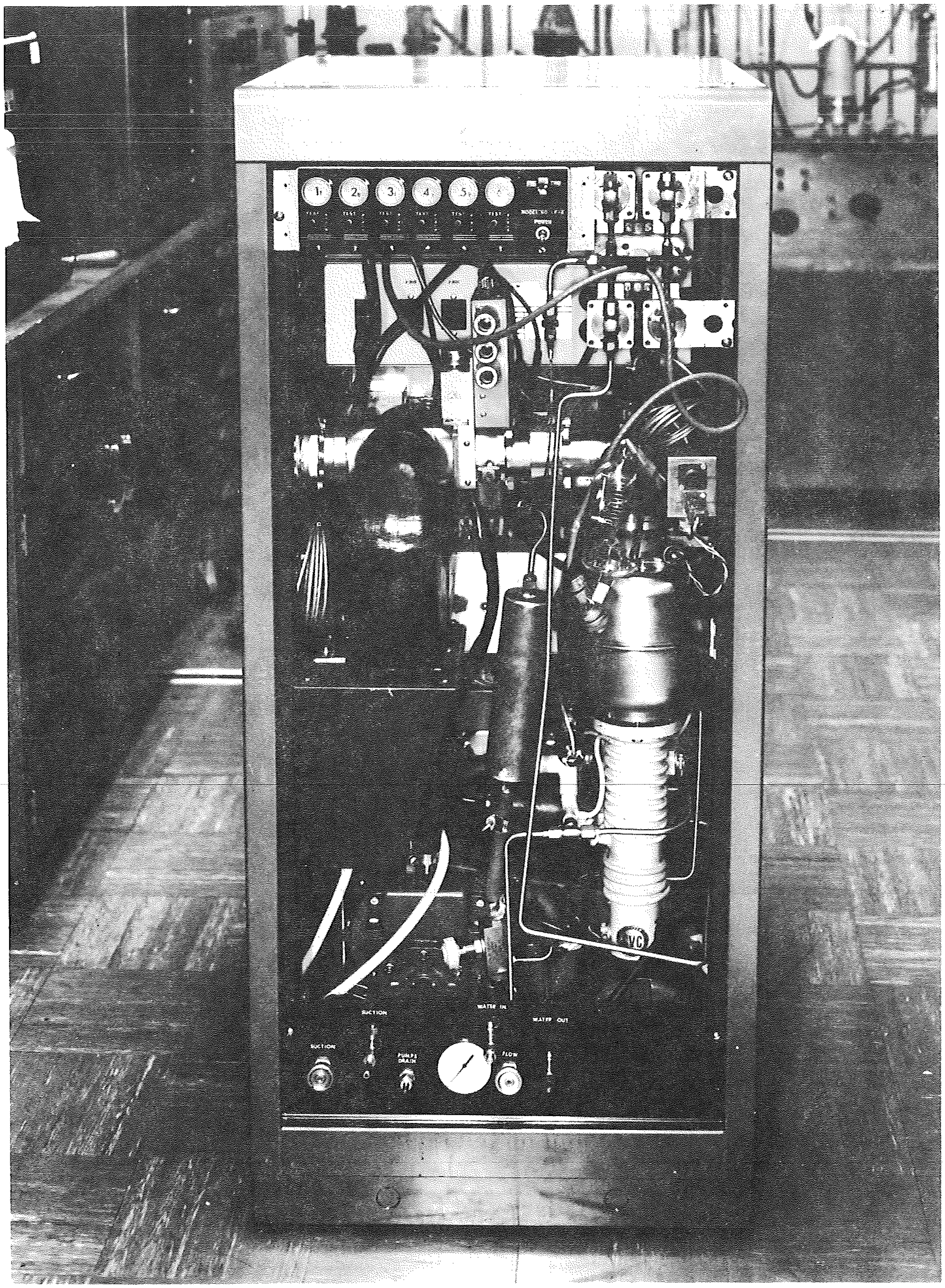

FIGURE A-22. - HAZARDOUS GAS DETECTOR, REAR VIEW

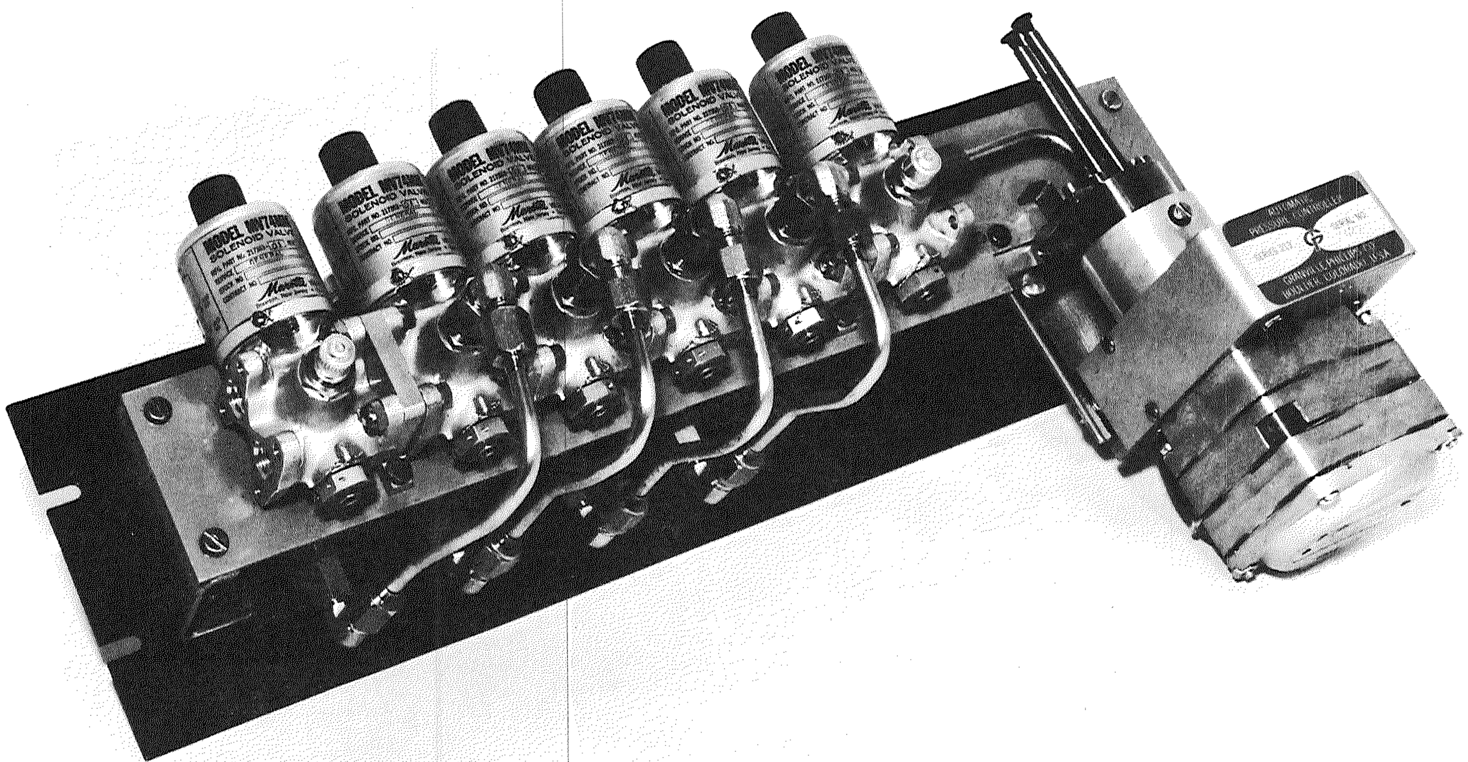

FIGURE A-23. - SAMPLE VALVE MANIFOLD AND SERVO VALVE DURING ASSEMBLY

April 3, 1968 NASA TM X-53720

APPROVAL

DESIGN AND DEVELOPMENT OF THE HAZARDOUS GAS DETECTION SYSTEM FOR LAUNCH VEHICLE PROPELLANT LOADING AND CHECKOUT

By C. L. Perry, A. C. Krupnick, and R. J. Harwell

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

J. R. Nunnelley
J. R. Nunnelley
Chief, Chemistry Branch

J. E. Kingsbury
J. E. Kingsbury
Chief, Materials Division

W. R. Lucas
W. R. Lucas
Director, Propulsion and Vehicle Engineering Laboratory

DISTRIBUTION

DIR	Dr. von Braun
R-P&VE-DIR	Dr. Lucas
R-P&VE-V	Mr. Aberg
R-P&VE-VO	Mr. Jacobi
R-P&VE-VOS	Mr. Lamb
R-P&VE-VOS	Mr. Duke
R-P&VE-VX	Mr. Varnedoe
R-P&VE-VR	Mr. Haire
R-P&VE-M	Mr. Kingsbury (5)
R-P&VE-M	Mr. Zoller
R-P&VE-MC	Mr. Nunnelley (25)
R-P&VE-MCC	Mr. Barnes
R-P&VE-MCC	Mr. Wells
R-P&VE-ME	Mr. McKannan
R-P&VE-MM	Mr. Cataldo
R-P&VE-MN	Mr. Curry
R-P&VE-P	Mr. Paul
R-P&VE-RM	Miss Scott
R-ASTR-IMP	Mr. Reiss
R-ASTR-PR	Mr. Caruso
R-QUAL-PI	Mr. Batte
R-TEST-ID	Mr. Schuler
R-TEST-IC	Mr. Blake
R-TEST-II	Mr. Kastanakis
R-TEST-B	Mr. Marsalis
R-TEST-BP	Mr. Ellner
I-V-MGR	Dr. Rudolph
I-V-E	Mr. Bell
I-V-SIC	Mr. Urlaub
I-V-SII	Mr. Godfrey
I-V-SIVB	Mr. Duerr
I-V-G	Mr. Smith
I-V-G	Mr. Etheridge
I-I/IB-MGR	Col. Teir
I-I/IB-G	Mr. Dunlap
I-RM-M	

DISTRIBUTION (Concluded)

GD	Dr. Debus
LV	Dr. Gruene
LV-INS-2	Mr. Fitzgerald
LV-INS-22	Mr. Jorolan
LV-INS-22	Mr. Helms
LV-INS-22	Mr. Bassett
LV-INS-22	Mr. Olufs
DE-ESD-2	Mr. Rogers
LV-MEC-24A	Mr. Mahoney
LV-TOM-3	Mr. Martin
LV-TOM	Mr. Pickett
LV-TOM	Mr. Rainwater
DE-MSD	Mr. Zeiler
MS-IP	Mr. Ziak
MS-IL	Miss Robertson (8)
MS-H	Mr. Akens
MS-T	(6)
Dep-T	

Scientific and Technical Information Facility (25)
Attn: NASA Representative (S-AK/RKT)
P. O. Box 33
College Park, Maryland 20740